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THE ONE-MAN TOWN

BY JOHN GOUGH

I have wondered in the past and am still wondering, as I attend these meetings, just how many of those present can claim the title of representative from a one-man town. By that, I mean a town or a city wherein the burden of administering the affairs fall almost entirely upon the shoulders of one man. In my own case, I am staggering under the combined titles (but not salaries) of clerk, water commissioner, street commissioner and chief of police. Incidentally, I may as well state that I am the only cop on the force.

In dealing with this subject, it is my intention to give some idea of the trials and tribulations of such a combination. I hope my audience will bear with me if I seem at times to incline to the humorous side, as without humor my position would be unbearable.

I am not writing this article with a view to enlightening my hearers or readers as to the solution of the many problems that occur to tax their minds. I took over the duties above named with but little experience to back me up and through actual contact with the ques-

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A paper presented before the Montana Section at Lewiston, April, 1937, by John Gough of East Helena. As the author indicates, his official titles are various. The paper is a most unusual one—a very human story of the activities of a water works superintendent in a small town. It doubtless has its counterpart in many other American towns and villages whose good fortune it is to command the services of such men as the author of this paper.

tions and through learning the little wrinkles gleaned from these meetings and otherwise, I have managed to keep water flowing, streets passable, collections well up to date and the city quite peaceable.

I have not been a regular attendant at these meetings but in no case where I have been present have I heard any discussion relative to the problems of the one-man town except in a general way as affected by the well organized departments of the larger cities. I have listened with a somewhat awed attention to discourses on the higher planes of water and sewer manipulation, grabbing here and there some point that has worked to my benefit, but usually feeling that most of it has gone completely over my head. The larger cities, with their full department membership and greater financial ability to meet their needs, can readily assimilate and digest all the information to be obtained. This is not the fault of the association that conducts these meetings but rather the fault of the little fellows in not demanding their share of attention. At times I have felt the urge to get on my feet and ask a question concerning some phase of water works management but realized only too well that in so doing I would only betray my ignorance. I have learned my lessons alone, whereas I felt that the others had gained a thoroughly technical knowledge.

At that, I do not doubt that many of the smaller city officers could give a wealth of pointers on water and sewer administration, if they could but be pried loose. I will here cite one instance in my own tenure of office as water commissioner that might at some time prove of vast help to anyone confronted with the same difficulty.

East Helena has a gravity water system, the intake dam being located on McClellan Creek at a point five miles above the city. Two miles out we have a storage reservoir. One bitterly cold day about four years ago I noticed the pressure gauge had dropped from the normal reading of 100 pounds to slightly more than 40. If a leak, I knew it must be a large one, and as no report had been phoned in as is usual in cases in-town leaks, I concluded it must be on the main feed line. It was 22 degrees below zero and storming, and only a couple of hours until darkness would come on.

A trip to the reservoir revealed no leaks below that point. A look into the tank disclosed the startling fact that where there should have been a 24 foot depth of water there were only six feet, enough to last the town about five hours. I followed the line to the intake

without finding the trouble. At the intake, however, I made a most disconcerting discovery; the dam was full and a good flow going over the spillway but the bottom of the basin was covered with a thick coating of ice, showing clearly that the basin had been entirely drained a short time before. A plate covering the meter hole in the steel line in winter was removed and I found the steel line completely filled with ice. A test showed 200 feet in this condition.

My job at that moment was to find some means of supplying water to the town in time to prevent the stoppage of circulation in the system, which with the condition of the ground at that time would have meant a complete freeze-up. And it was a one-man job, for I was all alone. You can bet that I did some frenzied thinking for a few minutes. Then a bright idea hit me. Hurrying to a point below where the line crossed below the creek channel, I dug a trench and uncovered the pipe at the bank. Then I took a hammer and chisel and cut away a large section of the top. A few minutes later I had a stream of water running into that hole from a hastily constructed coffer dam. That temporary intake system supplied the town for the next four days while we thawed out the frozen sections and it is now provided with a saddle and clamp for easy removal in case of a repetition of this trouble. Upon investigation I found that the dam had gone dry and the creek flow had been stopped by a heavy fall of snow, which was later shaken from the trees, the severe cold finishing the job of freezing countless dams to retard the water. Old time residents along the creek said this was the first time such an occurrence could be recalled, but what has happened once may happen again and we are prepared for it. There are many other systems in this state where a like situation could occur and where they are fortunate to have the line cross the creek below, and to these this incident may prove a helpful idea.

Getting back onto the main track of this article, I feel that perhaps I may have given the impression that I am the sole lord and overseer of the city affairs; we have a very efficient mayor and a loyal city council of four. They certainly are to be given credit for the work they do. But, in the final summing up, it is the clerk, the water commissioner, street commissioner or the chief of police that carries the job through and in the majority of cases also starts it, carrying it to the council for approval or disapproval.

Recently I have made daily notes of my work, hoping that some one day's happenings would furnish a typical cross section picture of

what one man in a one-man town must face. Last Thursday, April 15th, came the nearest to hitting the mark. Here is what happened: 8 A.M.—Having a crew of three men on pipe repair work, I lined out the day's work for them. 8:20 A.M.—Called to dispose of a dog that had bitten a child. 8:55 A.M.—Took out the street grader for a couple of hours work levelling a block that had been torn up in repairing water line. 9:25 A.M.—Called to investigate case of bachelor not having been seen about house for three days. Found doors and windows closed and had no response to calls. Broke in and found man sick in bed, no heat, no food and no drink. Had isolated himself to starve to death. Turned case over to county authorities and resumed grading. 10:20 A.M.—Called to office to furnish information to interested party concerning proposed sewer system. 10:55 A.M.—Back on grader. 11:20 A.M.—Called by foreman pipe crew to advise as to proper way to remedy defect in line. 11:35 A.M.—Back on grader. 11:55 A.M.—Delinquent water user stops grader to offer payment on bill. Have to go to office to check dates. 12:25 P.M.—Go to lunch; find two telephone calls to be made, parties calling wondering why I am not in office forenoons. 1:15 P.M.—Back on grader hoping to finish job before 2 P.M., regular office opening time. 1:25 P.M.—Gooseneck on private line on Morton Avenue springs leak, go to shop and get key and turn water off. Bring in man to dig out main line connection. 2:10 P.M.—Run grader in shed and go to office. Find two customers asking why office is not open on time. Spend next two hours writing up records of minutes and other office data. 4:15 P.M.—Resident of Pacific Avenue calls to inform me that irrigation ditch crossing her lot is blocked up and water flooding property; spend ten minutes trying to locate farmer's water tender by phone without result. 4:25 P.M.—Go to headgate myself and reduce water flow. 4:50 P.M.—Back in office to find several parties waiting to get information regarding chances for sub-contracts on sewer system. 5:25 P.M.—Decide to lock up and get out, being 25 minutes past closing time now. Just get vault and safe locked when belated customer appears to pay water rent. Re-open and accommodate her. As she leaves telephone rings. Party at other end of line informs me that two cows have entered her yard and are eating the lilac bushes. 6 P.M.—I have the cows safely corraled and am on the way home. Two blocks from home I am stopped by a householder who claims his water has stopped running for no apparent reason. Investigate

and find his young son has turned off the basement valve without his knowing it. And thus ends the day. But not always thus for it is not an uncommon occurrence to be called at any hour of the night for almost any cause.

The above related diary of one day may give you some idea of the variegated duties of the one man in a one-man town, but in my particular case it does not cover all angles. From the years 1916 to 1925 I was employed at the smelter as first aid man and employment manager. In this line of work I had occasion to visit perhaps every home in the what was then a town and become familiar with the home life of every employee of the plant. I became somewhat of a personal advisor. In addition to all my other troubles this unrecorded job still stays with me. I hope you will pardon me if I cite a couple of illustrations.

One day a young foreigner, showing considerable agitation, called on me. After several apologetic remarks I learned that he wished me to act as his proxy in proposing to his intended wife. I asked him why he could not handle the job himself and he informed me that he did not believe his expectant father-in-law cared for him. When asked why he thought so, he replied that when he had called there the evening before the old man had kicked him out into the street. I declined the position as proxy.

On another occasion I was awakened before 6 A.M. by an excited man who insisted that I come immediately to his home and see what was the matter with his wife. She had severe stomach cramps and in spite of everything he had done she had enjoyed no relief. I suggested that he call a doctor, but as the nearest doctor was in Helena he insisted that I come. I did. I asked him what he had done to relieve her misery. He informed me that he had rubbed her abdomen well with liniment, a product that was being freely distributed from the smelter clinic. Imagine my surprise when I found her "midships" colored with a deep coat of blue. He had, in the dark, grabbed the bottle of washing bluing.

All in all, life for the one man is a continual series of troubles, intermingled with bright periods that relieve the monotony. Spring presents its problems in line and tank flushings, repair of frost struck sections, street repairs, city cleanups, etc. Summers, such as we have had for the past several years, bring on torrid tiffs with the farmers accusing the water commissioner of appropriating more than his share of irrigating water; the subsequent regulating of sprinkling

hours and the constant game of hide and seek to detect those violating the rules. Fall presents its problems of preparing for the rigors of winter, such as testing all fire hydrants, again flushing mains, regulating bleeders, etc. Winter demands the cleaning of streets and sidewalks, the keeping open of roads governing our waterworks, quick action on frozen lines and the constant supervision of the intake to insure a steady supply of water. Heretofore I have not been concerned with the multiple duties that accompany the operation of a sewer system, but within the next few months these bugaboos will become stern realities. Bonds have been sold and the contract awarded for a complete sewer system.

The one man job in a one-man town is a hard and often a heartless position but I would not trade it for many of the special department jobs so well represented here. The one man job has a human side to it that is completely lost in the more aristocratic position. Special department jobs mean routine hours, cold blooded business procedure and almost invariably clock regulation. The one man jobholder is permitted to regulate his hours according to the pressure of his duties; if it storms outdoors, he can nearly always arrange his work to be indoors; if sunny weather prevails outside, he can always find something to do away from the office; if he feels a bit out of sorts and lonesome, he can invoke his police powers and make a tour of whatever route he may desire; no matter where he may wish to go, he can always find an excuse for going there.

In closing it is my fervent wish that all those attending this or similar meetings of the American Water Works Association give all the attention due to the one-man town question and that those representing these small but important communities step up to the front and assert themselves as the circumstances may require.

FIRE PROTECTION FOR SMALL TOWNS

By R. C. Dennett

In the small town, as in the larger, two features must be considered in the design and operation of a water works, from the standpoint of fire protection; adequacy and reliability. These features must extend through the entire system, from the source of supply, whether it be from surface water or from wells, the supply mains, the pumping station and equipment if pumps are used, the suction and discharge piping, and the distribution system. It is one thing, and a very important thing, to be able to deliver the required fire flow to the point of demand, when the system is functioning under normal conditions, but it is also of greater importance that the supply be delivered under unusual or adverse conditions. A sudden cold spell may come early in the season causing anchor ice to clog the intake. A pump may go out of service and it may take several days or weeks to repair it. A break may occur in discharge piping which because of improper arrangement or gating may cause a complete shutdown. A break in the distribution system may occur, which, bad enough at the best, may be aggravated because too few gates have been installed making it necessary to shut off several blocks. These are a few of the features which, while not relatively as important as in a large system, will give much food for thought to the superintendent of the water system in a small town.

Many things have been said, and written about all these features, but today we will discuss particularly the question of pumping equipment, for adequate and reliable service.

For domestic consumption, a normal estimate is 100 gallons a day per capita of population, with maximum days of 150 gallons per capital. Peak loads will occur considerably in excess of this amount, but it is considered reasonable to provide for a fire demand in excess of the maximum day rate, rather than the peak hourly load which

A paper presented at the meeting of the New Jersey Section at Newark, May, 1937. The author, R. C. Dennett, is Engineer of the National Board of Fire Underwriters stationed at New York, N. Y.

occurs only for a short period and for comparatively few days in the year. This means that for a place of 500 people, a delivery capacity of only 50,000 to 75,000 gallons a day is needed for average domestic operations. For economic operation it is usually advisable to provide pumps of somewhat larger capacity, especially where elevated storage can be provided, thus permitting intermittent pumping.

For fire service, however, there is always a demand, even in the small communities, for at least two fire streams, and if there is any close grouping of buildings, or buildings are of large size the need will increase to 4 or 6 streams. This means that there must be provided a minimum of 500 gallons a minute, corresponding to a rate of 720,000 gallons a day, with up to 1,500 gallons a minute or 2,160,000 gallons a day for a place of 2,000 population where the maximum consumption demand would be only 300,000 gallons a day.

It is evident, then, that fire demand in pumping equipment is eight to ten times that for domestic use. There has been a rather general thought that this fire demand can best be met through elevated storage. Elevated tanks of capacities up to 2,000,000 gallons have come into quite wide use; they have operating advantages in permitting more uniform pumping rates, providing for peak domestic load demands and also, of course, for fire reserve. The factor of reliability of service, however, must be considered in studying the question of pumping capacity, which cannot be entirely offset by elevated storage, unless it is large. Pumps and prime movers must, occasionally, be overhauled and repaired and this usually requires a period of time longer than that through which the elevated storage can last. Therefore, in any system, it may be accepted as an axiom that at least two pumping units must be provided, either of which must be able to supply the domestic consumption and probably a part of the fire supply.

Most small systems are adopting electric power for the prime mover. Here again the reliability factor is of considerable moment. Electric lines are nearly always overhead and therefore subject to interruption from wind and sleet storms and other causes. Power lines sometimes have insufficient capacity for full fire demands, and in some cases the number of transformers or capacity of the generating station are not sufficient for full adequacy and reliability of supply.

It may be stated, then, that in practically every water works

system where electricity is used for pumping there must be a certain number of units having some other source of power, if adequacy and reliability of fire service is to be maintained. This of course will be modified by the elevated storage available.

The other forms of prime movers are steam plants and internal combustion engines.

Steam plants, unless in connection with some other use, are expensive in first cost and maintenance and will seldom be considered in connection with small water works. Even where steam operation is now used, and a change to electric power is contemplated, it is generally economy to abandon the steam plant entirely.

The economical fire standby and reserve for small communities, is the internal combustion engine. There is little upkeep or maintenance expense. The first cost is also relatively low, and the operating crew need seldom be more than the one man who would normally operate the electric equipment.

In sections where natural gas is plentiful and cheap, gas engines may be the most economical type, but at present they are not much used. In connection with the growing practice of handling liquefied petroleum gas in bulk it may be that the use of gas engines will increase.

The use of diesel engines is increasing. These are very effective, both as regular service units and as reserve equipment. The first cost is relatively high, but operating cost is low and their general suitability is good. They can be obtained in almost any size.

The other form of internal combustion engine is the ordinary gasoline engine. It is believed that too little study has been given to the possible use of the automobile type of gasoline engine for waterworks operations. Generally when the question arises as to the use of a gasoline engine the thought is that an expensive, specially designed machine must be used. In fire department operations, all pumping is now done with automobile engines. There seems to be no good reason then why, for fire purposes, the water works plant cannot use the same type of engine. Consider, first, the power required. To pump 1,000 gallons a minute against 60 pounds pressure, there would have to be developed 35 horsepower. With a conservative power factor of 60 per cent this would mean an engine horsepower of 60 which is well below the usual power of such engines as the Ford, Chevrolet, and other commercial cars of low cost. Available on the market, at reasonable cost, are other engines, up to and in some

cases exceeding 200 horsepower, which means that pumping capacity, against 60 pounds pressure, can be obtained up to 3,700 gallons a minute.

While the gasoline engine is not ideal from the standpoint of economical operation and therefore not to be considered as a rule for continuous duty pumping equipment, the cost of running such an engine for fires, for while the regular service equipment is being overhauled, will not materially increase the yearly cost of the plants operation.

It would therefore seem that any small community could well consider making its pumping plant consist of one or two electrically operated units of sufficient capacity to care for maximum days' consumption, with gasoline pumps for emergency and fire service.

For the place of 500 population the arrangement could be one 100,000-gallon a day electrically driven centrifugal pump with one 1,000-gallon a minute gasoline pump for fire and emergency. In places requiring a fire flow of 1,000 gallons a minute two of these gasoline driven fire pumps could be used. In like manner three of these units should be provided where 1,500 or 2,000 gallons fire flow are needed, and 4 for 2,500 to 3,000 gallons.

This method of pumping for fire and emergency use seems well worth the consideration of water superintendents in small municipalities.

FACTORS IN THE SELECTION OF MOTORS FOR WATER WORKS PUMPS

By H. A. Bartling

In this paper motors for pumping equipment ranging from 1 to 6 m.g.d. capacity will be considered. A total head of 200 feet has been assumed as average. With these capacities and heads the motor horsepowers will be:

For pumps of 1 and 1½ m.g.d. capacity, the speed will be 3,600 r.p.m., requiring a 50 and 75 h.p. motor respectively.

In capacities of 2 to 6 m.g.d., the pump speed will be 1,800 r.p.m. with a corresponding horsepower range of 100 to 300.

If the total head is higher, or lower than the assumed 200 foot value, the horsepower required to drive the pump will vary proportionately. At larger capacities slower speed pumps would be considered.

For water works pumps at average heads it is not essential to vary speed and, therefore, a slip ring motor will not be considered. Thus the selection of the type of motor will lie between a synchronous and a squirrel cage induction machine.

For 3,600 r.p.m. pumps, it is suggested that squirrel cage induction motors be used. The power factor of either a 50 h.p., or 75 h.p. motor at 3,600 r.p.m. will be 90 per cent and the efficiency will be approximately the same. A two-pole synchronous motor is a costly machine and its efficiencies will not be much better than those of the cage motor.

For the 1,800 r.p.m. pumps the cage motor should also, be chosen. A synchronous motor at 1,800 r.p.m., including standard control, will cost from 100 per cent to 25 per cent more than the cage motor in ratings of 100 to 300 h.p. The higher percentage in cost will apply to the smaller rating, tapering down to the low percentage at the larger rating. Unless necessary to provide power factor correction

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A paper presented at the Wisconsin section meeting, at Green Bay, November, 1937, by H. A. Bartling of the Allis-Chalmers Co., Milwaukee, Wisc.

it will be more economical to use cage motors in this horsepower range.

In comparing synchronous or cage motors of 1,800 r.p.m., some thought must also, be given to the difference in efficiencies between the two types. The efficiency of an 80 per cent power factor synchronous motor at this speed will be .3 or .4 of 1 per cent better than the efficiency of a cage motor at the same rating. The unity power factor synchronous motor at 1,800 r.p.m. will average approximately 1½ per cent better efficiency than the cage motor at the same rating. This slight difference in efficiency in favor of the unity power factor synchronous motor is hardly sufficient to offset the higher first cost.

Cage motors do not require separate excitation, which must be furnished with the synchronous machine. This excitation will ordinarily be provided by means of a direct connected exciter, the cost of which has been included in the percentage price difference given between synchronous and cage motors at 1,800 r.p.m.

Standard voltages recognized by the various electrical manufacturers are 220, 440, 550, 2,200, 2,300 and 4,000. This range of voltages should cover the ratings under consideration. For cage motors up to and including 200 h.p., a 2,200 volt machine will cost more than a 440 volt motor. A 2,200 volt motor, including standard control will cost from 40 per cent to 15 per cent more than a 440 volt machine in ratings of 100 to 200 h.p. Above 200 h.p., the difference in control will constitute the only difference in price, as the price of the motor alone will be the same for either 440 or 2,200 volts. In many cases a 440 volt control at the larger ratings will be more expensive than the 2,200 volt control.

With synchronous motors above 75 h.p., the motor price will be the same for either 440 or 2,200 volts. The control price will vary in accordance with the condition mentioned for the cage motor.

The use of 4,000 volts is not advocated, but if necessary, the minimum rating recommended is 75 h.p. For cage motors, the price above that of the 2,200 volt machine will vary between 40 per cent and 20 per cent for ratings from 100 to 200 h.p. The cost of the control will also, be materially higher for 4,000 volts. Existing conditions may make it expedient to specify 4,000 volt motors, but this will be the rare case, not the rule.

The final selection of the voltage for the motors will depend upon the voltage which is available from the power company lines. We are assuming that the incoming line voltage of the power company

system will be such as to require the use of a step-down transformer for any voltage 2,200 volts, or below. Where a single motor is to be installed, either 440 or 2,200 volts may be selected irrespective of the cost, depending upon local conditions. With the single motor it might prove expedient, due to its size and to reduce copper in leads to motor, to use a 2,200 volt machine.

If other motors are in the same station probably it would be more economical to provide a transformer with suitable ratio to a lower voltage such that all motors may be operated from the one transformer rather than using a 2,200 volt motor and stepping down for smaller ratings to a lower voltage. In the majority of cases, we feel that either 440 or 2,200 volt motors will be used.

In selecting between cage and synchronous motors, the power factor of the respective machines is also, a factor. The power factor of a 3,600 r.p.m. cage motor will be approximately 90 per cent and for the 1,800 r.p.m. machines about 92 per cent. It is well known that, if a cage motor is only partially loaded its power factor is materially decreased. Since the pump load for the water works stations we are considering is such that the motors are either operating at full load, or shut down, it is only necessary to consider the full load power factor of the motor. In selecting the motor rating for the pump care should be exercised to select a rating as close to the actual pump b.h.p. as possible. In most cases it is not necessary to provide a motor having overload capacity for pump drive, since all motors have the well-known 15 per cent service factor.

If the pumping unit is installed in a plant where it is necessary to provide corrective effect for the lagging power factor of other motors in that station, it may be advisable to use synchronous motors. The actual determination will, in a large measure, be dependent upon the clause included in the power company's contract relative to the charge made for low power factor. At the present time, the usual power contract rate is based on two charges: first, a maximum load, or a demand charge based on a flat rate per kw. of maximum load per month. The other portion of the rate is an energy charge, or load charge, which is an amount per kw. hour. Thus, the penalty for low power factor applies only to the maximum load charge portion of the total bill. Since the price of the 1,800 r.p.m. synchronous motor is inherently higher than that of the cage motor, it may be shown on any particular installation, even if corrective effect is required, that it is more economical to use a cage motor as a pump

driver and provide the power factor correction by other means. To determine which is preferable for a specific installation, a careful check of cost of each type of machine should be compared with the saving, if any, in the total power bill, by raising the plant power factor.

Before issuing specifications on a contemplated installation, it is well to obtain from the power company, the maximum starting current, which they will permit on their lines. We are now assuming that the cost of the synchronous motor will eliminate its use on the 1,800 and 3,600 r.p.m. pumps.

For cage motors up to 300 h.p. at 440 volts, the starting current will be approximately 750 per cent for Class "A," and 550 per cent for Class "B" motor. Class "A" refers to N.E.M.A. Classification for a normal torque, normal starting current motor, and Class "B" is a N.E.M.A. Classification for a normal torque, low starting current motor. The Class "B" motor is more expensive than the Class "A". For 2,200 volt motors, starting currents will be 800 per cent for Class "A" machines and 600 per cent for Class "B" machines. Percentages given are on the basis of normal full load current, as 100 per cent. If the power company will not permit a starting current of 550 or 600 per cent, which may be obtained from the Class "B" motors, reduced voltage starting of some means will be necessary. If reduced voltage is required, Class "A" motors should be used, since they are lower in price, unless current limitation given by the power company is so low as to make it difficult to meet the limitation by means of a single step control.

If the Class "A" motor requiring 750 per cent starting current at full voltage is purchased, a single step control will probably reduce the current to about 300 per cent from the line. Usually, this should be acceptable to the power company, but occasionally it has been found that the limitations set are extremely low. To meet these very rigid requirements, additional steps on the control are required, materially increasing the cost. It is difficult to give a percentage increase in cost for an additional number of steps, but a rough approximation would be that the standard control of one step would be increased in price by 100 per cent for a two step control. You can readily appreciate it is to your interest to see that the lower company limitation is reasonable, such that it will not require your city to purchase an expensive control equipment.

If the starting current limitation set up by the power company is

such that two or more step control must be purchased, it is necessary that the manufacturer know the permissible increment per step. This increment is not always the same value as the initial block of current permitted by the power company.

Usually, we are quite positive the standard reduced voltage starter will be acceptable to the power company. You will note that by using a Class "B" motor, where the full voltage starting current is 200 per cent less than on the Class "A" machine, another means of meeting a low current limitation of the power company is available without increasing the number of steps on the control.

The selection of full voltage starting or reduced voltage starting will largely depend upon the starting current limitations set up by the power company. In some locations the power companies will undoubtedly permit full voltage starting, but in other cases, due to the loads on their lines, or other extenuating circumstances, the power companies must insist on lower starting current values, which automatically require the use of some type of reduced voltage starting equipment.

The choice of magnetic, or manual control will be governed somewhat by the proposed installation. Manually-operated control equipment may well be used, if an operator is always available, or, on duty at the station. In cost manual control equipment is approximately 50 per cent of a full magnetic control. If the station is to be an isolated one where the operator will probably make an inspection once, or twice a day, or week, automatic control should be used, irrespective of its cost. Thus, if by the use of an automatic control the services of an operator may be eliminated, the automatic control should be used, but if an operator is always required at the plant, then manual control should be given serious consideration.

Manually-operated reduced voltage control equipment will be approximately 10 to 15 per cent of the combined pumping unit total price. With magnetic control equipment, control percentage of the total price will be increased to 25 to 35 per cent.

Magnetic control will probably be governed from a pressure, or altitude switch. The motor will then be connected to the line in case the pressure in the water main drops to too low a value and will be disconnected after this pressure is built up to a preset value. Even with manual control, it would probably be well to provide a connection to the manual control, such that the motor will be disconnected from the line, in case the pressure in the water main be-

comes too high. This is more, or less of a safety measure and will apply especially to an overhead tank installation.

Some attention has been given in recent years to enclosed control. There are many types of enclosures for control equipment, varying widely in price.

It is possible to obtain a sheet metal enclosure for the standard control, which we have referred to previously. With this type of enclosure, the standard panel is used and mounted inside the enclosure without any special protective devices. The standard control price with this light enclosure will be increased by 10 to 25 per cent.

A cubicle type of control is being used extensively at the present time. A cubicle is an indoor stationary metal enclosed structure providing mounting accommodations and containing the switching, protective, indicating and metering equipment. It provides complete isolation of high potential circuits from the low potential circuits. The primary switching devices, such as oil circuit breakers and busses are bolted in place and located inside the enclosure. Cubicles can be relatively inexpensive, with only a minimum amount of safety features, or many desirable safety features can be included, which, naturally, increases the price.

It is difficult to compare the price of a cubicle with that of a standard control, inasmuch as so many additions may be added to the cubicle type control. By adding all the protective devices in a cubicle control, the cost will closely approach a metal clad unit. It is, therefore, desirable that a decision as to the amount of safety features required on the control should be reached.

A metal-clad unit consists essentially of two structures; a stationary structure and a removable structure. The stationary structure includes the primary busses, instrument transformers, cable wiping sleeves for receiving incoming, or outgoing cable and the necessary instruments and relays. The removable structure consists only of the oil circuit breaker element. Provisions are made between the stationary and removable element for disconnecting both primary and secondary connections. The metal-clad control is the most expensive of the three, and in many cases will be from five to ten times the cost of the open, standard control.

The selection of enclosed control will depend somewhat on the service intended for the proposed station. If it is an isolated unit, not open to the public, enclosed control would probably not be necessary. If it is a "show" station, where many inexperienced people

would be apt to come in close proximity to the panel, it would be well to provide some enclosure for protection and a more pleasing appearance. The item of cost would also, enter into the decision. If the enclosed control is required, it is suggested that information be obtained from some manufacturer before specifications are issued. Any reputable manufacturer would be pleased to discuss the control for a contemplated installation.

Pumps having larger capacities than mentioned in the first paragraph of this paper, will have speeds of 1,200 r.p.m., or lower. For these units the synchronous motor is to be preferred for the following reasons: The cost of the synchronous motor is comparable, or less than that of a cage motor. The synchronous motor is more efficient; a synchronous machine operates at unity power factor or if corrective effect is required, can operate at any leading power factor.

The remarks made relative to the starting current limitations set up by the power companies would also, apply to the synchronous machines. The standard torques which have been adopted by N.E.M.A. for synchronous motors will be ample, in the greater number of cases. If low speed units are considered, that is; 450 r.p.m., or lower, some attention should be given to the pull-in torque specified for the synchronous motor. If the pump must start with the discharge valve open, or with a check valve in the discharge, a pull-in torque of at least 100 per cent should be specified for the low speed synchronous motor. If the pump will always be started with the discharge valve closed until after the motor is synchronized on the line, a lower pull-in torque, resulting in a lower motor price, is permissible. The high pull-in torque is to be preferred for pump service.

In selecting equipment for a proposed station, the following factors should, therefore, be considered before specifications are issued:

1. Type of motor, whether cage or synchronous motor, with cage machine preferred at 3,600 and 1,800 r.p.m.
2. Voltage which depends upon plant conditions and power company system.
3. Starting current limitation as imposed by the power company. If this value is exceptionally low, a statement from the power company as to the peaks which will be permitted per step should, also be obtained.
4. Control, whether manual or magnetic, open or enclosed, reduced voltage, or full voltage, and statement of interrupting capacity required for oil circuit breaker.

THE ETHICS OF CONTRACTS GUARANTEEING WELL CAPACITY

By George Arnold

The City of Bozeman purchased its water works from a private owner in 1899. The supply, at that time, was estimated to be sufficient for a much larger population than is now served. All proposals to meter all water have been strenuously opposed. In general, meter rates have been out of line with flat rates. The flat rate for sprinkling lawns and gardens has been so low as to border on the ridiculous. These conditions fostered a rapid increase in per capita consumption, so that to meet the demand, the city has been availing itself of every opportunity to acquire additional water rights whenever this could be done at reasonable cost. Finally the point was reached when there were three possible ways to add to our supply; drill wells, build storage reservoirs, or buy farms with water rights.

In 1935, we drilled a 6-inch test well hoping to reveal conditions comparable to those prevailing in Missoula, where wells of large capacity were developed a few years ago. In drilling this test well, our driller's equipment was designed for farm wells and his experience was limited to wells of small capacity. However, he did the best he could and finally got a hole down 300 feet. He kept a log as required by the State Board of Health. While he encountered some water fourteen feet below the surface and was apparently in water bearing formations (so far as he could tell) nearly all the time, he felt sure, at the end, that the material was so tight or non-porous that the water would not flow through it fast enough to give us a well of sufficient capacity to be of real help. As he expressed it, he had "a good farm well." We tested it with an air lift and got 160 gallons per minute with a forty-five foot draw down. So far as I could see, his conclusions were sound; and we were not at all encouraged by the results of

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A paper presented at the meeting of the Montana Section at Lewiston, April, 1937. The author, George Arnold, was at the time of the meeting, City Manager of Bozeman, Montana. He was drowned while engaged in water department activities early in September, 1937.

the test well. Moreover, we had gone through the summer of 1935 without having to restrict use or hours of irrigation, so we decided to await the outcome of efforts to effect the construction of a large Federal Aid dam proposed on the West Gallatin River, which would indirectly make available additional water for our supply.

The winter of 1935–36 produced a very light snowfall in our water sheds; and at the end of May, we had had three months of very subnormal rainfall, and we were becoming very anxious about our water supply and our wishful thinking naturally turned to the well as the most likely prospect of getting results in time to do us any good. We had been studying the problem and thought that if we got a hole of large diameter we could possibly develop a worthwhile well by some sort of gravel pack method.

It happened that a rotary outfit, which had been used to drill two prospect oil wells, some twenty-five miles west of Bozeman, was being moved through Bozeman to a job east. This being the only outfit of adequate size in our part of the state, we asked the owner for a proposal. After study and discussion of the log of the test well and the pumping test, he offered to drill a hole 300 feet deep and case it with 20-inch "second run" oil-well casing for $2,750.00. He was very enthusiastic and sure of getting us a large capacity well. He said to me, "I'll get more water than you can pump." So I said, "If you are so sure of that, what will you take to guarantee us a yield of 1,000 gallons per minute?" He said he would have to have something to cover his risk and that he might have to go deeper than 300 feet to get 1,000 gallons per minute so would add $750.00 and would make us a price of $3,500.00 for a well yielding that quantity. I thought he was too optimistic, so I took him out and showed him all the geology I knew. But he felt that he knew a whole lot more than I and that was all right with me. It was easier for me to go to the City Commission with a proposal for a well at a guaranteed capacity of 1,000 gallons per minute for $3,500 than for a hole for $2,750 with no guarantee.

As dry as it was at the time, the City Commission couldn't turn down a proposal for such a well at such a price, and we entered into a contract with the driller. Had the price been materially larger, we probably would not have made a contract because of lack of confidence in getting satisfactory results. The contract provided that the hole should be not less than 300 feet deep; should be cased the entire depth with "second run," 20-inch oil-well casing, and should

yield 1,000 gallons per minute. If the finished well met these specifications, the driller was to receive $3,500.00 upon presentation of proof that he had paid all claims for labor, material, etc., used for the well. If the yield on test should be less than 1,000 gallons per minute, he was to receive only $1,500. The City was to furnish the testing equipment, (the driller didn't have any). The only hitch in the proceedings was that the driller refused to give a bond. He said he had gone through a lot of hard luck on his last oil-well operations, and was in no shape financially to give a bond and he wouldn't make an effort to arrange one. It was a case of take it or leave it and by that time we wanted water badly enough to take it; so a contract was signed without the usual bond. It later developed that the driller expected to drill the hole in one long shift or that it would not take more than two or possibly three days at the longest; and that he could recover the casing required from an abandoned oil well near Belgrade at practically no cost, but the labor for pulling it. In short, he thought he had a cinch on some easy, quick money. We of the city thought if he was successful, we would have a cheap well and if he was not successful it would be worth $1,500 to know that wells would not solve our problem. Except for the matter of the bond, there was no difficulty in arriving at the terms. The driller named them and the City accepted them.

Drilling was started at daylight, June 25th, and the depth of 300 feet was not reached until the evening of July 15th. He wasn't able to start the casing in the abandoned oil well, and had to give it up. The City purchased 300 feet of 20-inch casing for the driller. He got 160 feet of this in the hole, but could get no more down. My personal opinion is that the hole is crooked. We got him 140 feet of 10-inch casing which he landed at approximately 300 feet from the surface. So we have a 300-foot well cased with 20-inch casing 160 feet and with 10-inch casing the remaining 140 feet; instead of a well 300 feet deep cased to the bottom with 20-inch casing. On test the well developed a capacity of about 450 gallons per minute. The well was not completed in time to be of any use to us during the summer. In view of the "hard luck" encountered by the driller, the City Commission offered to overlook his failure to comply with the specifications as to size and the failure to develop the guaranteed capacity and tendered the full amount of the contract, $3,500.00. This offer was not accepted. The driller's manager and his attorney filed claims against the City for about four times the maximum

contract price. The City, out of sympathy for the laborers, compromised the labor claims. We think the material claims cover a lot of supplies not used in drilling the well. The driller's wife claims wages of $12.50 per day as his manager and his attorney asks $100.00 per day for rental of equipment for 45 days. These claims have not been paid.

Our experience has suggested that a discussion of the ethics of contracts involving guarantees of capacity of wells might at this time be beneficial.

In the first place, the question of whether or not a contract is ethical or non-ethical is answered by the success or failure of the project. In our case, if the driller's anticipations had been correct, in other words if he had really known his stuff, he could have made big money; the city would have had good value for its money; and there would be no question about the ethics of the contract. The driller's keen judgment would have been vindicated, and most everyone would have said he was entitled to reward for his ability to see further underground than the rest of us. That would be just and fair; no one could say there was anything non-ethical about that. However, he did not know his stuff, and he failed, so the question of the ethics of the contract is posed for discussion.

In essence, this question of the ethics of contracts guaranteeing well capacity seems to be the same as the ethics of gambling as compared to speculation and investment. Law seems, in its efforts to define these terms and to distinguish between them, to stress motives, particularly in reference to balancing amount of risk to *assurance* of gain as opposed to *hope* of gain. As I understand it, the law says you are gambling when you risk money without reasonable assurance of *any* gain in the hope of a *very large* gain; you are investing when you risk money with material assurance that you will not lose the principal with the expectation of moderate earnings. Speculation lies some where between.

Gambling is, of course, non-ethical, speculation questionable and investment entirely ethical.

Let us approach our problem from that angle. The city wanted a well. The money it had to pay for the well was public money. It did not know if a good well could be had. It had certain information which it was inclined to interpret as an unfavorable indication that a well could be developed. A professional driller was shown this information and the city's interpretation of it was discussed with

him. He did not agree with that interpretation. He thought he saw a good chance to gain material reward because of his judgment, skill and abilities. He thought he knew where he could get some low cost casing. He did not seek to take an undue advantage of the city's need, but rather to share with the city the advantageous circumstances of the situation feeling confident that there would be very material mutual gain for both parties and that neither party would be loser. I thought, at the time, and I still think that he was sure of his ability to judge geology; that he could make a good profit at the figure he quoted and that did not name a higher figure because his anticipated profit would be reasonable and not burdensome for the city to pay.

Doubtless, he also had some ideas as to the results of naming too high a price. He knew that the city did not share his optimism and questioned his interpretation of the log of the test well. He knew that the city was not willing to hazard any considerable amount of money unless it had some assurance of a material quantity of water. The city was willing to and did assume the risk as to quality. In a nut shell, the situation was this. It was proposed that we undertake a rather hazardous undertaking. In every business undertaking, there are inherent risks. An ethical contract is one in which these risks are equitably distributed between the parties to the contract and a reasonable compensation is awarded the contractor for his risks and costs, and the other party gets reasonable value for its money.

In the distribution of these risks, both parties being free agents, each assumes the risks he is willing to assume; both are assumed to know and be able to evaluate each and every risk inherent in his part of the undertaking, and to evaluate, in addition to the inherent risks, other possible risks as well as conditions which he can control. Any party awarding a contract surrenders a considerable amount of control over operations. The only way he can protect himself is to require a guarantee of results. If he does not avail himself of such a guarantee, he lays himself open to unlimited abuse and loss. So it would seem that there is nothing inherently unethical in a contract effected within these limitations.

We think it is good business, whether or not it is required by ethical standards, to give a prospective bidder the advantage of all the information we have available on a given project. We think it is good business to spend time and money to eliminate as many risks as can

be eliminated at reasonable cost. This naturally involves drawing lines that are difficult to draw. Even so, there will always remain a residue of unknown factors.

After all is said, each individual case probably must be determined pretty largely on the circumstances surrounding it.

My personal conclusion is that while there is nothing essentially contrary to sound ethics in contracting to guarantee quantity of production (except in thoroughly proven territory), a contractor is foolish to do it. He certainly is foolish to risk more than he can afford to lose.

THE RELATION OF WATER WORKS TO AUTOMATIC FIRE PROTECTION

By Winthrop M. Jones

I was brought up as a boy in Water Department work. My father was the whole works in the water department of a town not far from Boston for some 43 years. We had a model pumping station on the outskirts of the town, pumping from reservoirs of clean water fed by artesian wells. There were two pumps, condensing, pumping to a standpipe of about 300,000 gallons capacity on a hill, which fed the whole distribution system.

From custom, father operated the pumps from about 8 A.M. to 2 P.M. every day (never stopping until the standpipe was overflowing) and the standpipe took care of the supply for the balance of the day. Other hours of the day were spent in repairing mains, fixing hydrants, laying new mains, and fixing meters. My work started with handing my father and others the proper tools in the trench, and ended with operating the pumping station when father was sick.

There were two good size sprinklered plants in town,—the shovel and tool works and the shoe factory. I didn't even know then what a sprinkler head was, in fact had never heard of one. The systems were fed solely by city water.

One night there was a fire at the shovel works. We got up to the station and started up the pumps. With an hour's pumping we couldn't even maintain standpipe pressure, and what was worse, the pressure steadily dropped. Father concluded that a main had broken and sent me downtown to see and report back. I saw the whole works ablaze and from various hydrants water was just dribbling out, with one good stream from a pumper, which by that time didn't do a bit of good. On returning we pumped and pumped, until about daybreak the pressure suddenly jumped up—and with a day more of pumping we finally overflowed the standpipe. There were

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A paper presented at the meeting of the New Jersey Section at Newark, May, 1937. The author, Winthrop M. Jones, is Special Representative of the Factory Insurance Association of Hartford, Conn.

big shots from all over the country in town after that—with hearings at the Town Hall for days—and my father was on the spot. Those men wouldn't even believe a recording gauge dial! The story got around that my father wasn't on the job—and instructions were issued to the effect that the standpipe water level had to be maintained at a certain point, no matter how often the pumps had to be operated. This was done for years, but the black mark against my father remained to the end.

Later, it developed that a new building at the shovel plant was being equipped with automatic sprinklers, and on the day of the fire the connection to the main had been made and the valve left shut, the connection at the riser not made and the feed line just sticking in through the basement, wide open. This basement drained into a water wheel tail race. At the start of the fire someone opened that valve and the mill, sprinkler system, water works' reputation and father's spirit, all went down into that tail race.

I tell this rather personal story which made such a lasting impression on me, not to give automatic sprinklers or water works black eyes, but to bring out the value of one to the other—to show the need of knowledge of automatic fire protection by water works men. You sometimes hear of automatic sprinkler failures and a great deal of talk goes around to the effect that they aren't any good. The trouble with automatic spinklers is not with the device but with the men who monkey with them.

An automatic sprinkler system consists of a lot of spraying nozzles held closed by fusible links, attached to pipe lines under water pressure, located close to the ceiling. They are installed in every room, every nook and corner, each head covering from 70 to 100 square feet, depending upon the construction of the ceiling and upon obstructions to distribution of water. Each individual system is fed by a riser which is controlled by a valve, in town or country risks outside, and in city risks usually from a manifold in a vault. Usually we have a water flow alarm valve in each riser to give a signal when water flows.

We have special systems and special spacing for various out-of-the-ordinary occupancies,—in fact, some of the recent sprinkler systems remind me of some of Rube Goldberg's cartoons. But to get down to standard systems, we have special close spacing for rooms in which celluloid is used or stored, dry pipe systems for freezing locations, and some arranged to discharge foam on tanks containing flammable liquids, etc.

The erroneous impression persists that sprinklers may be omitted in heavy fireproof buildings. Just as a stove is fireproof and the contents burning within can heat it red hot, a fireproof building may be so heated and damaged by the burning of its contents. Therefore, unless the character of the contents is strictly noncombustible, sprinklers are installed just as though the building were of timber construction.

These sprinkler systems in practically all of the large industrial plants and in a big proportion of the small plants, are fed by two or more separate water supplies. The water supply which maintains pressure on the system normally is called the primary supply, and the other supply or supplies which come into play automatically at the drop in pressure of the primary supply are called the secondary supplies. By far, city water takes first place as a water supply for automatic fire protection systems. Next comes the gravity tank for primary supply which is anywhere from 10,000 to 200,000 gallons in capacity, and next the fire pump, usually for a secondary supply, and in the large cities the pressure tank which contains only a limited amount of water under high pressure for a primary supply.

You are at once concerned with the details of connections between the plant's own water supplies and the city supply. You are rightly concerned with the chances of pollution by means of these connections. Here is where a difference of opinion arises between water works men and insurance carriers. You will find insurance people in sympathy with your desires to secure a positive separation between the two, to the extent of providing potable water for the private supplies to be impressed against the check valves in your city connections. You will find that although we may believe that approved double bronze check valves in a city connection offer a safe means of preventing contamination, we do not go very far in opposing the ruling that there shall be no cross connections whatever, and we work with our policy holders toward a revamping of the system and a substitution of private supplies such as will meet the requirements in retaining the valuable city supply.

I want to emphasize this point, that while we fight for the maintenance of existing private supplies in connection with a city water supply, we do it in such a way as not to oppose your principles, and in many, many cases have we helped you with your customers and our clients in bringing about the desired results.

Another point which concerns us both, possibly more in the past than it has done lately, is the size of connections for fire protection.

Many details govern this, but with few exceptions the need of a plant as to size of connections is readily met by water works men. There are yet some who probably feel the fire protection system is no good; that water will be stolen and the smaller the connection the less will be taken; and hold down the size of such a connection to a ridiculous level. These are few and far between. The general rule is a maximum size of connection one size smaller than the street main. This seems fair enough to us.

Some perhaps have wondered before now why such large city connections are required. It is true that the great majority of fires in properties protected with automatic sprinklers are extinguished by the water from one or two or three heads. For instance, in our own records for the year involving several thousand risks, the average is actually six heads opening per fire. The average number of heads operating per fire on all risks throughout the country is said to be in the neighborhood of 5. Under average pressure conditions, one head will discharge about 30 gallons per minute, so that six heads would be 180 gallons per minute, and these heads would not operate probably over a half hour at the most, which is to say that the average fire would take possibly 5,000 gallons to extinguish. Indeed, a tremendous proportion of fires are extinguished by the operation of one or two heads.

However, from our own records, there was one fire opening 219 heads, which would require a flow of some 4,000 gallons per minute to give satisfactory distribution. This is a tremendous flow. There were quite a few which operated 75 or 80 heads, and any number which operated 25 heads. In other words, in fire protection work we have to figure upon the unexpected, upon the chances of something going wrong such as a broken pipe, a broken fitting, a draft causing heads to operate not in the zone of fire, a valve closed at the wrong time by mistake, corrosion in and plugging up of pipes, etc.

If there is a fire, water must be used to put it out. The automatic sprinkler is the most efficient device for distributing water. It puts every bit where it belongs, and puts it on the fire in the form of a spray which is about six times heavier than the heaviest rainfall ever recorded. You can well imagine the drenching you would get from a downpour six times as heavy as any downpour you have ever seen. Therefore, if there are no sprinklers to extinguish a fire, water will have to be used from hose streams, and such a method will take from 10 to 1,000 times as much water. You secure a revenue from the metered water to a fire protection system, but you do not,

I believe, from water used from the public hydrants. It is economy therefore to supply fire protection systems, and the more systems installed the less will be the emergency need from the public water system. It is not an uncommon occurrence to find that in the event automatic sprinklers have not extinguished a fire due to something unforseen, it has taken a million gallons or two million gallons to do the work.

Help to secure large and many fire protection connections. You already know the importance of keeping pressure on the system at all times, of course. But even now our inspectors find cases where automatic sprinkler systems have been without water for days at a time, due to shut-offs in the vicinity with no notification whatever. I do not mean systems in one-horse towns either, for in a good sized city right here in your own state, city water as the sole supply was shut off for several days and no notification given. Help to keep pressure on at all times. Be sure to give customers notice when repairs are to be made in order that they may take the necessary precautions against fire.

There is one other point which I have not touched upon, rather purposely and that is the much discussed question of charges for fire protection service. There are books and books written on this subject and many discussions about it held at your several meetings in times gone by. Charges in cities, usually flat charges depending upon the size of the connection, range from zero to several hundred dollars per year. Indeed, some companies charge so much per hydrant per year and others so much per sprinkler. A case has just come to my attention of a proposed charge of $100 per hydrant per year plus 12½¢ per sprinkler per year. There appear to be arguments on both sides as to charges. The mere maintenance of pressure by a water works on a system certainly carries an overhead on equipment and operating investment, even though no water at all is used. On the other hand, assuming a bad fire in a mill with no city connection and, therefore, no revenue to the water department, plenty of water would have to be furnished toward extinguishment by means of public hydrants.

You will find Insurance Inspectors always watching out for service connections on any fire protection system, since it is a fundamental rule in sprinkler work not to permit a combined system,—so you may count on our continued cooperation in keeping a sprinkler system free of service use.

MOVING THE SPRINGFIELD WATER WORKS

By S. T. Anderson and Charles H. Spaulding

Public water supplies are sometimes outgrown as are the suits of growing boys. They can be stitched, patched and lengthened for a time, but eventually they may have to be discarded and replaced with new and more suitable material and fashion. Such a time, when it comes, is an opportunity to build for the future and fortunate is the community whose water utility is in a financial position to make the most of the opportunity. Once established, a water supply may and should last for many years with only the changes required for additional units of capacity and minor modifications of treatment for improved quality. A public supply which has made this change should have definite contributions to make to the progress of water supply engineering. It is the purpose of this paper to briefly describe some features of the Springfield development which we believe have some novelty and merit.

On Dec. 2, 1936, the new water softening plant went into continuous operation at Lake Springfield and the entire supply of water for the City of Springfield hereafter will be derived from this artificial lake. This statement which seems so simple to write, tells the culmination of a period of continuous and consistent development extending back more than 25 years. It may be said to be the result of a policy of administration involving especially several definite principles, none of which has been maintained without a struggle, but each one of which has been demonstrated to be essential. Before discussing the policy, let us review the changes which have recently been made.

THE NEW WATER SUPPLY

The old water supply, constructed in 1868, after a delay due to the Civil Water, had its source at the Sangamon, and so it continued for

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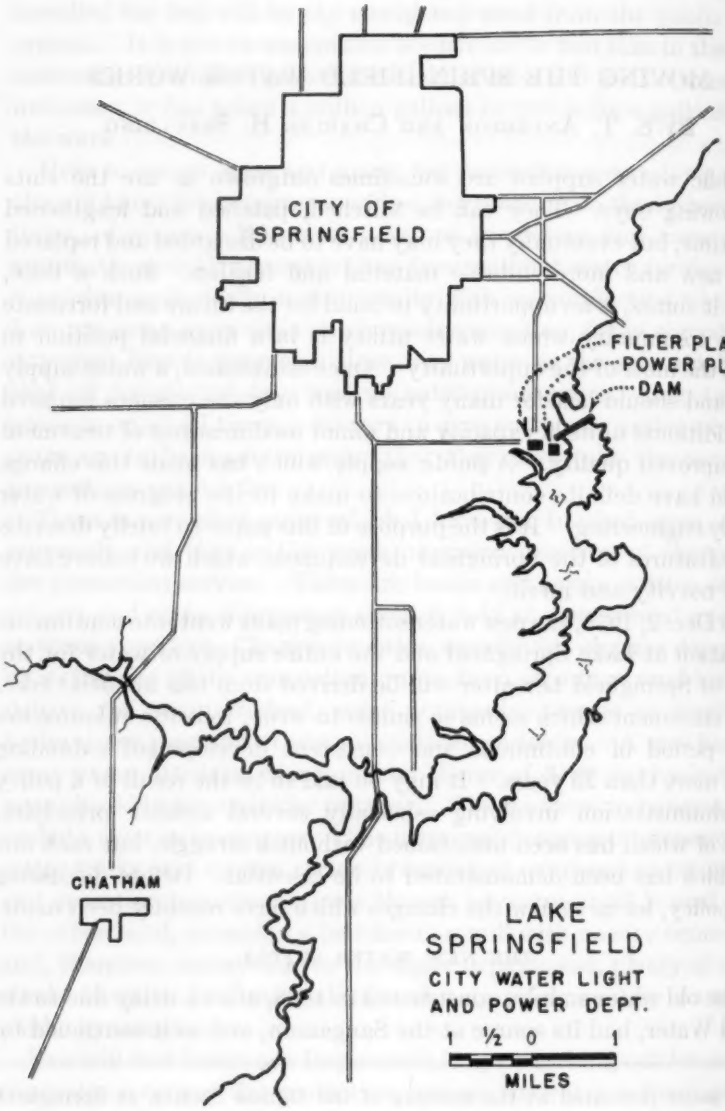
A paper presented at the meeting of the Illinois Section at Springfield, April, 1937.

The authors are S. T. Anderson, Superintendent of the City Water, Light and Power Department, and Charles H. Spaulding, Superintendent of Filtration in the same department at Springfield, Illinois.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MILES

60 years in spite of increasing pollution from the cities above and the threat of floods. By the beginning of the twentieth century, the typhoid fever death rate in Springfield was averaging 40 per hundred thousand population and so continued until 1912, despite the downward trend of the average for the registration area of the United States. In 1912 a marked improvement was made in the quality of the water by the substitution of well water from shallow driven wells in the river bottom. A drop in the typhoid death rate followed. 1918 showed another marked improvement, coincident with the beginning of chlorination. Another marked drop in the typhoid fever death rate occurred in 1926 at the time of the installation of the water purification plant at the river and has continued since. However, the quality of the Sangamon River water itself has not improved, for there are times when it is one of the most highly polluted sources of water supply, as measured by the *Esch. coli* index.

Aside from the problem of water purity however, it was apparent that the city had about reached the limit of water resources in the old location at the river, for during drought periods, the combined yield of the wells and river was not more than 12 million gallons per day and our peak daily consumption had already passed this figure. Another bad feature which probably was never sufficiently appreciated was the dangerous location of the plant with reference to possible floods. It was estimated that a 75 year flood would have put this plant out of service.

When the lake project came to the fore, several studies were made on the Sangamon River to determine the cost of an artificial lake in this valley. It was found that the natural topography of the valley, as well as the location of railroads, highways and coal mines would make this project cost some $10,000,000.00, as compared to another project on Sugar Creek at a cost of about one-fourth as much. Furthermore, the quality of the water on Sugar Creek would be many times superior to that of the lake on the Sangamon which contains the sewage of the City of Decatur. Accordingly the Sugar Creek project was adopted. Work began in 1930 at the very beginning of the depression. The project was financed by corporate bonds of the City of Springfield in the amount of $2,500,000.00, with the promise that at least one-half of the burden would be borne by the water department. So far, all payments of principal and interest have been made by the department from earnings and it is hoped all future payments may be so made.

Thousands of men were given employment on the project, directly and indirectly. At a time when, in some cities men were raking leaves, in Springfield they were clearing the site for the new reservoir. Later, when the construction of the lake had been completed, the extensions of the water and electric utilities again absorbed much unemployment. Part of this work was done under PWA financing.

Before the completion of the lake, a second step in the development of the new supply was taken. This was the laying of a transmission main from the site of the proposed power plant and pumping station to the city. The purchase of pipe for this line was financed entirely from funds of the water department. The labor was furnished from the relief rolls of the city.

SEWERS

To control the sanitary conditions of the lake water and shore, it was decided to construct sewers in the areas that seemed likely to be the most popular residential locations. Under Work Relief, CWA and WPA, 12 miles of sewer lines, 9 pumping stations and 2 syphon chambers have been built. The sewage from about three-fourths of the area served by this sewer system is collected and pumped to a disposal plant located on the east side of the lake. This plant consists of a screen, Imhoff tank and sludge drying beds. Chlorine is added to the sewage at the last pumping station. Final disposal is into a neighboring creek. The sewage from the other one-fourth of the area on the sewer system is collected and pumped into one of the sewers of the sanitary district of the city. In the area not served by sewers, but where water is available, small separate disposal systems may be installed for individual homes. These systems consist of small Imhoff tanks discharging into tile disposal systems, and despite the fact that the ground is very tight, a number of these systems have been working satisfactorily. In other areas where neither water nor sewers were available, septic toilets which use little water are permitted.

WATER MAINS

All of the marginal land surrounding the two largest basins of the lake is supplied with water mains connected to the city distribution system. This consists of approximately 15 miles of mains in sizes from 4-inch to 12-inch. All of these mains were constructed by the city under PWA grant, except that section on the west side of the

lake from the Vachel Lindsay Memorial Bridge to the Auburn Pumping Station, west of Cotton Hill. This section of the main was constructed by the six towns south of Springfield, namely: Chatham, Auburn, Virden, Girard, Divernon and Pawnee, which are now supplied with city water, each town having its own distribution system. The village of Rochester has connected to our lake distribution system on the east side and is supplied direct from the city pressure, except in case of fire, when an automatic fire pump goes into operation.

ELECTRIC LINES

A total of 25 miles of electric lines has been constructed around the marginal land, making available the same low electric rates as apply within the city of Springfield. A number of the custodians at the lake have taken advantage of this facility to construct electrically heated homes.

PARKS

To encourage orderly recreation at the lake, the department has set aside and improved a number of parks. The most important of these is known as Lake Park, which consists of a picnic grove, baseball diamonds, horseshoe courts, public boat dock, beach and beach-house.

The sand beach is U-shaped, 800 feet long, 250 feet wide, with a total shore line of approximately 1,300 feet. Diving towers, chutes, and other beach equipment make the beach enjoyable, and trained life guards make it safe. A breakwater separates the beach from the rest of the lake to protect the sand from wave action and to keep raw lake water out of the pool. A thousand-gallons-per-minute pump operated continuously, delivers water treated with chlorine into the pool through a perforated pipe 400 feet long laid in a trench below the sand and under 3 feet of water.

The beach house is built of rough stone and will accommodate approximately 10,000 people in one day. It includes a large veranda for spectators, a restaurant, showers and dressing rooms. Three other Public Parks have been set aside for recreation in which fireplaces, lights, water, tables and toilet facilities have been provided.

Another large area has been set aside as a wild life sanctuary, most of which is not open to vehicles but is traversed by trails. It includes about 6.35 miles of shore at the most inaccessible part of the lake between the two main tributaries. The program in this

area is the protection of birds and small animals with a minimum of artificial improvements.

An area of sixty acres has been dedicated as a Lincoln Memorial Garden. Under the sponsorship of The Garden Club of Illinois, this garden is taking on the character of a national memorial.

Several other parts of private or semi-private nature help to complete recreational facilities of this type.

REFORESTATION

Much of the marginal land of the lake had been in cultivation prior to purchase by the city and was devoid of trees or other vegetation. No standard practice or policy was known which would be directly applicable to our set of conditions so that in some respects we have had to pioneer as to tree planting and landscaping. It was deemed advisable, however, to cover this area with trees and sod in order to protect it from erosion, as well as to add to its beauty. Sod was immediately established on all marginal land except in areas in which conifers were closely planted. The sod was started by a liberal use of timothy and rye, as well as blue grass and other grasses.

Those areas of the marginal land to be used for residential and park purposes have been planted mostly with native hardwoods. Certain other areas, remote or unsuitable for residential use have been planted with conifers as thick as one thousand per acre. Some of these have now reached heights of 10–12 feet and the protective influence on the soil is becoming effective through the mat of needles lying on the surface as well as the extensive root systems underground. Most trees have been bought as small stock one to two years old, costing on the average about 0.5 cents each. They have been placed in our own nursery for 1 to 2 years before planning in the field. About half a million trees have passed through the nursery and been set out in the field. Of these, it is estimated about half have survived droughts and are started toward maturity.

The purpose of erosion control by reforestation and sod is of course two-fold, in that it controls turbidities and retards the rate at which the reservoir will lose its usefulness as a source of water supply by silting.

RIPRAP

During the construction of the lake, all highway and railroad fills were riprapped to protect them against erosion by wave action. In

addition to this, the city has now completed protection of nine miles of additional shore where the exposure to the waves is most severe. Forty-five thousand tons of riprap were used for this purpose,—was practically all handled with floating equipment. The rock was received on cars and unloaded directly into skip boxes which were then placed on barges and towed to the site of the work. There the rock was handled by a derrick boat.

ROADS

With the cooperation of the State and County Highway Departments, improved roads have been built around the main basins. The department has constructed and maintained approximately 18 miles of secondary roads through the parks and cottage areas.

CUSTODIANS AND THE MARGINAL LAND

Income from the marginal land is expected to maintain the area and pay something toward retirement of the bonds. Last year revenue from various sources was approximately equal to the maintenance and operation charges. Just what amount will eventually be contributed to bond retirement remains to be seen. If the income increases, as expected, without corresponding increase in operating costs, a material contribution may be possible. Lake bonds will be retired by 1951. Likewise, three-fourths of the lease value of the custodians' tracts is amortized during the first 20 years leaving a smaller amount to pay during the last 40 years of the lease. This smaller payment is to provide for future maintenance. The term "custodian" is applied to the lessees whose obligations include a certain amount of cooperation in enforcement of lake regulations.

Leased tracts are irregular in size, shape and desirability. They lease for various prices ranging from $40.00 per annum to several hundred dollars per annum for the first 20 years with the reduction mentioned for the balance of the term.

The custodian may use the premises for residential purposes and may build on the property but all building is subject to regulation of the department as to its type and location.

Many of the farms which were purchased for lake purposes had houses as well as other buildings and structures. Most of the buildings were demolished but the houses were repaired and modernized or remodeled to a considerable extent so as to be suitable for renting

or leasing. There are 27 such houses, 9 of which were leased for 60 years and 18 on short terms. Thirty-three houses have been built by custodians, either for summer or year round residential purposes. Eight more are under construction. Now that the pioneering stage of lake residence is passing, its popularity is rapidly increasing.

In a large part of the area, water, sewerage and electric service are available at city rates. These are best adapted for year round dwelling. However for the use of vacationists who require less elaborate dwellings, a grove of some 40 acres has been utilized for a group of 25 three and four room cottages which are leased for the season at rates from $200 to $300.

WATER SOFTENING PLANT AND PUMPING STATION

The water softening plant replaces one which was located on the Sangamon River and embodies a number of novel features, notably combination tanks or precipitators in which the mixing and settling are combined to go hand in hand by improving the softening and coagulating reactions.

All of the water works equipment is located in this present section of building and consists of the following: Two low service electric pumps, one $7\frac{1}{2}$ and one 12 m.g.d. (one $6\frac{1}{2}$ m.g.d. electric pump now being installed), three high service pumps for pumping the filtered water into the distribution system, one $7\frac{1}{2}$ m.g.d. and one 12 m.g.d. pump, both electrically driven and one 15 m.g.d. steam turbine driven centrifugal pump.

The pressure from the electric pumps is controlled by automatic cone pressure regulated valves. The pressure from the steam unit is controlled by the speed of the unit, which is regulated by a pressure controlled governor.

The plant has not been in operation long enough to determine accurate costs, but it appears that there will be an important saving in operation at the Lakeside Station over the old River Station, as this plant is 50 feet higher and the equipment is much more efficient. Chemical costs formerly $8.00 per million gallons are expected to be approximately $4.00 per million gallons.

A water supply improvement project as extensive as the Springfield project ordinarily necessitates an increase in rates in order to pay its way. In the present instance, a rate increase has not been required, notwithstanding that rates are lower than the average for

cities of like size and under the same conditions as to water supply. There are four principal reasons why this is the case.

First of all, it may be mentioned that during the past 25 years politics have not played a part in the selection of employees in the water department and due to the continuity of management there has been a minimum overturn of personnel. Moreover, a continuity of policy has been possible which has prevented false starts and futile beginnings.

The second principle, now generally recognized, which was inaugurated some 25 years ago, is the payment for water in proportion to quantity used, in other words, the substitution of meters for a flat rate. When this practice was begun it resulted in the circulation of a petition for the recall of the Commissioner. Fortunately, the public learned the soundness of the policy in time to prevent its defeat.

The third principle is the prevention of diversion of funds from the water revenues into other extraneous projects. In this, the management has succeeded better than some others less fortunate. No fire hydrant charge is made in Springfield and it must be admitted that this constitutes a diversion of some $60,000.00 a year of water revenues to furnish this free service. There is also a gift of $4,000.00 to $5,000.00 worth of free water to the State Fair grounds each year under the terms of an old agreement with the state, made more generously than wisely by city fathers of bygone days. It should be clear that such diversion is false economy and wrong from the standpoint of good bookkeeping.

The fourth point is one in which the Springfield water department enjoys an advantage not possible to many other plants. This is its joint operation with a municipal electric department which shares its station and general expense.

TREATMENT OF LAKE WINNEBAGO WATER

By L. R. Howson

This discussion deals with the unusually intense taste and odor characteristic of Lake Winnebago water and the features of design and construction of two municipal plants for its treatment. Strange as it may seem, Oshkosh (which has used Lake Winnebago water for fifty years, beginning in 1884) was in 1934 seriously considering its abandonment in favor of wells as a source of supply, while Neenah, just twelve miles away (which has used an excessively hard well water from the beginning of its water works in 1893) voted in 1936 to go to Lake Winnebago for its supply.

The successful solution of both problems is an indication of the development which has been made in recent years in methods of improving the quality of water supplies, particularly with respect to tastes and odors. More progress has been made in that regard in the past few years than in all prior time and it may now safely be stated that practically any water can be delivered to the consumers free from taste and odor.

LAKE WINNEBAGO

Lake Winnebago forms a large storage basin on the Fox River in Central Wisconsin. The lower reaches of the river, before it enters Lake Winnebago, are swampy and contain numerous lakes of relatively large areas. Lake Winnebago itself is some thirty miles in length, has a width averaging eight miles, and is unusually shallow for a body of water this size, there being but very few small areas in excess of 12 feet in depth. There are many submerged reefs and islands extending nearly to the water surface. Largely as a result of its shallow character, the lake water sustains luxurious algae and other fresh water growths. It is stated that the name Winnebago was given to this body of water because the name in Indian means

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A paper presented at the meeting of the Wisconsin Section at Green Bay (November, 1937) by L. R. Howson, Consulting Engineer of the firm of Alvord, Burdick and Howson, Chicago, Ill.

"Stinking Water." Whether or not that be true, the name would be appropriate at many periods.

The peculiarly luxuriant algae growths in Lake Winnebago have been known and studied long prior to the time when the public became taste and odor conscious with respect to its water supply. The Wisconsin Geological and Natural History Survey published a pamphlet in 1903 entitled, "Plankton of Lake Winnebago and Green Lake," from which the following is quoted:—

> "The phenomena of the 'bloom' . . . is especially marked in Lake Winnebago in some summers. It is due, of course, to the enormous growth of plants of the plankton, that growth being particularly fostered by the hot weather of midsummers. . . . At the middle of August, in some summers, on a still day, the surface of Lake Winnebago is apparently a solid opaque green. Some of this material decomposes and as the currents slowly move along, the surface has the appearance of polished Malachite. Its intrinsic beauty, however, does not attract the average person as he looks upon it as 'scum' and thinks of it simply as an evidence of filth. This material is thrown upon the shores by the waves until the rocks along the shore are completely covered with it and it may in its decay become very offensive. Following the maximum period of the 'bloom' Cladophora appears and covers the littoral rocks with a thick mat of green. . . ."

The color of Lake Winnebago water near the entrance of the Fox River at Oshkosh changes rapidly, frequently from 40 or 50 p.p.m. to 200 p.p.m in one or two days. The lake serves as an equalizer and the variations in color, taste and carbon requirements are less pronounced in supplies further removed from the Fox River inflow.

THE OSHKOSH PROBLEM AND ITS SOLUTION

The original Oshkosh water works was completed and placed in operation in 1884 at a time when filtration was in its infancy. It was eight years later (1892) when Warren tub filters were installed. These continued in service until 1915 when the present modern concrete filter plant was built. This plant included an installation of "Multiple Inspirators to aerate the algae laden lake supply" (Eng. News Record—5/3/17). In 1932 these facilities were supple-

mented by spray aerators located on the roof of the unusually capacious settling basins.

It will be recalled that this section of the country was visited by a dry cycle in the period from 1930 to 1935. Probably as a result of that, with the more luxuriant growths in the lower rivers as well as in Lake Winnebago, the resulting tastes and odors in the Oshkosh water supply have been more accentuated than usual during recent years. By 1934 the situation had become so acute that although the water supply was safe bacterially, and powdered carbon has been used up to as much as 50 pounds per million gallons, the tastes and odors in the public water supply were so pronounced that there was a popular demand that the lake be abandoned as a source of supply and that a well supply be developed. About this time consulting advice was secured and following that advice the Oshkosh filtration plant was operated over an extended period as a full scale experimental plant to determine the practicability, methods and costs of taste and odor prevention and elimination applicable to Lake Winnebago water. It was recommended that these possibilities be exhausted in view of the economic losses that would result from the abandonment of a 6 million gallon filtration plant, intakes, pumping station and a distribution system built to distribute water from a central location, which would be impracticable if a well supply were to be adopted.

The experimental work at Oshkosh started early in July 1934 and continued until April 1935. It was desired that some experience be had with the water during all seasons. Daily observations were made to determine the odor threshold number of raw and tap water in both hot and cold samples and the amount of powdered carbon required for satisfactory results. An effort was made to feed the amounts of powdered carbon required whenever possible. However, during much of the time, due to the unusually large quantities of powdered carbon required, the carbon feeding facilities were inadequate. The data secured with the amounts which it was practicable to feed, however, formed a substantial basis for determining the practicability of carbon treatment and for estimating costs.

A granular carbon filter was operated to exhaustion in parallel with the application of powdered carbon, in order to determine the relative efficiencies and costs of powdered and granular carbon.

Other methods of taste and odor elimination were also tried such as ozone treatment, the combination of lime softening with filtration

and aeration, but the net result was that activated carbon furnished the most practicable and positive means of handling the taste and odor situation.

The test period showed conclusively that the carbon requirements on an average were much greater than had been anticipated and further, that the odors and tastes prevailed in Lake Winnebago water to a much greater extent and much more continuously than had been anticipated.

The year's experimental operation of the plant in which the detailed work was done by Mr. H. J. Schneider, and under the general direction of the engineers and of Mr. John R. Baylis, who cooperated with them, led to the following conclusions:—

1. Activated carbon was the most practicable and positive method of removing tastes and odors from the Lake Winnebago water. Whether the desired results were obtained by adding powdered activated carbon to the water followed by settling and filtering it out, or by filtering the water through beds of granular activated carbon, or a combination of the two, was a matter of economics.

2. The powdered activated carbon requirements based upon the test period varied from a minimum of 50 pounds per million gallons to the maximum of 300 pounds per million gallons at an annual average of 160 pounds per million gallons.

3. A granular carbon filter operated to exhaustion showed a capacity of 7,450 gallons of water per pound of granular carbon, the equivalent of 120 pounds of carbon exhausted per million gallons, when operated on a water having a powdered carbon requirement averaging 176 pounds per million gallons.

4. The efficiency of powdered activated carbon was approximately two-thirds that of the granular carbon. In view of the fact that the variation in price is materially greater than this ratio, and that powdered carbon requires only a nominal installation cost, whereas granular carbon filters are more costly to build and maintain, powdered carbon offers a cheaper method of taste and odor removal than the granular carbon under Lake Winnebago conditions.

5. The addition of lime for partial softening had no appreciable effect on odor reduction.

6. Ozone treatment of Lake Winnebago water was only partially successful.

7. Aeration of Lake Winnebago water demonstrated its inability to produce sufficient benefit to be worth while.

Powdered carbon offered the cheapest method of odor removal. Its application is subject to the human element. Granular carbon installed in filters is more costly but foolproof. In view of the extreme fluctuations in the quality of Lake Winnebago water, together with the local prejudice which had developed against it due to its tastes and odors, it was decided to install facilities for both powdered carbon and granular carbon treatment, the powdered carbon being utilized to do practically all of the work, and the granular carbon in filters to be built in series with the sand filters simply used as a safety measure and to provide complete assurance that no tastes and odors will pass the plant at any time.

THE OSHKOSH PLANT REHABILITATION

The Oshkosh filter plant was provided with a very liberal settling period. It, however, was operating without the advantage of a thorough mix. The plans which were developed provided for the installation of a rapid or flash mix with a motor driven propeller in a separate compartment having about five minutes detention period, followed by approximately thirty minutes slow stirring with equipment of the flocculator paddle type. The flocculator equipment is installed in the first of the four settling basins. It has been found practicable with this rearrangement of mixing and settling facilities to feed powdered carbon in quantities in excess of 300 pounds per million gallons and still have an influent to the filters carrying a turbidity of less than 7 p.p.m.

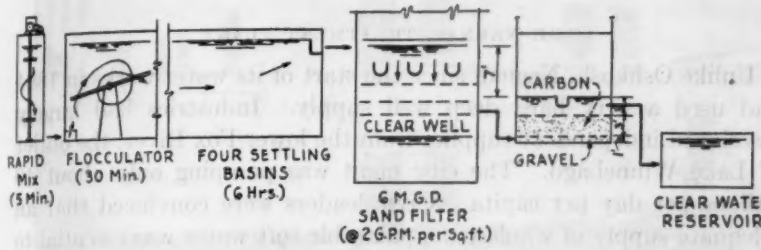
Four granular carbon filters each having a capacity of 1 m.g.d. were installed intermediate between the sand filters and the clear water reservoirs.

The carbon filters are of the upward flow type, the filter influent being taken directly from the effluent controllers of the sand filters. The underdrainage system consists of cast iron perforated pipes overlaid with 12 inches of graded gravel and 3 feet of granular carbon. There is a 3-foot freeboard between the top of the carbon and the lip of the trough. The effluent trough of the carbon filters is set so as to permit a maximum loss of head on the sand filters of 7 feet.

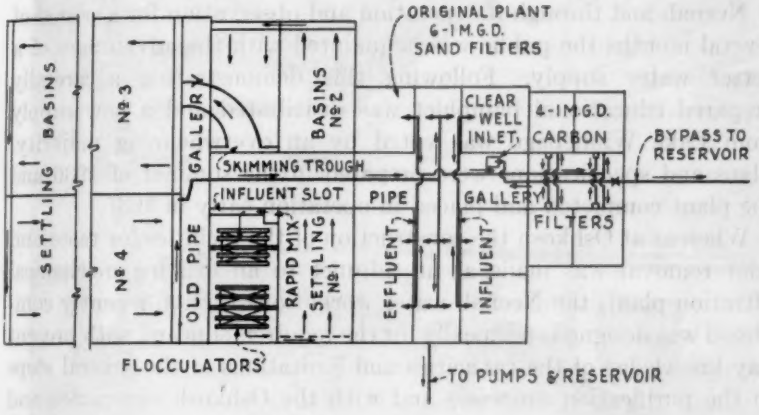
In order to prevent algae growths in the granular carbon filters,

the building housing the filters has no illumination other than from electric lights. No control other than the elevation of the effluent troughs is provided.

Competitive bids were taken on the granular carbon which was specified as 99 per cent passing a 4 mesh sieve and not more than 3 per cent passing a 14 mesh sieve and with intermediate gradations.



DIAGRAMMATIC CROSS SECTION



DIAGRAMMATIC PLAN

FLOW DIAGRAM - OSHKOSH FILTER PLANT

The carbon was purchased on a phenol adsorption number price adjustment basis.

The cost of that part of the Oshkosh rehabilitation program which had to do with the taste and odor elimination, was approximately $50,000—a very insignificant sum when compared with the value of the water works construction which would have been rendered value-

less had Lake Winnebago been abandoned and deep wells adopted as the source of supply.

The annual operating expense was estimated at $7,000 for powdered carbon and $1,000 for granular carbon filter maintenance, the equivalent of 20¢ per capita per year.

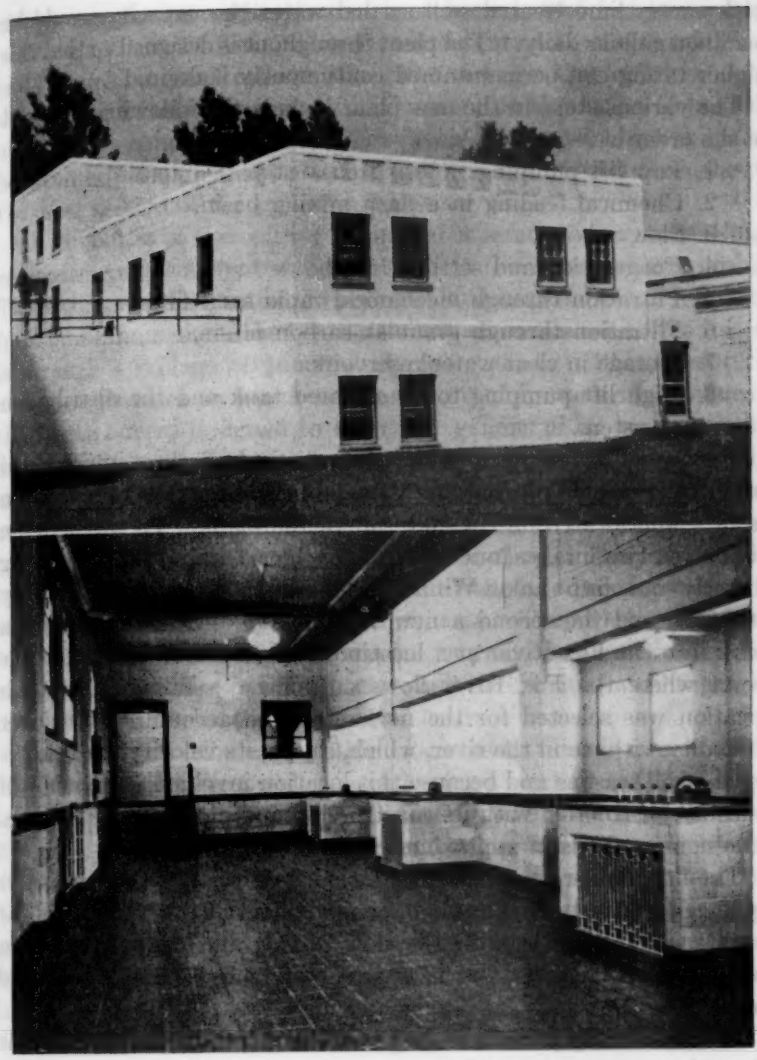
This work was all done under the Oshkosh Water Commission for which Mr. Albert E. Hintz is manager.

THE NEENAH TREATMENT PLANT

Unlike Oshkosh, Neenah since the start of its water works in 1884 had used a very hard deep well supply. Industries had largely developed independent supplies from the lower Fox River, the outlet of Lake Winnebago. The city plant was pumping only about 40 gallons per day per capita. Civic leaders were convinced that an adequate supply of wholesome, palatable soft water was essential to the city's growth. In 1935 and 1936 a demonstration filtration, softening, taste removal plant was built on one of the main streets of Neenah and through its operation and observation for a period of several months the public was acquainted with the advantages of a better water supply. Following this demonstration a carefully prepared educational pamphlet was distributed and a new supply from Lake Winnebago was voted by an overwhelming majority. Plans and specifications were prepared in the summer of 1936 and the plant completed and placed in operation early in 1937.

Whereas at Oshkosh the construction of the facilities for taste and odor removal was made as an adjunct to an existing mechanical filtration plant, the Neenah water works construction recently completed was designed specifically for the requirements and with present day knowledge of the capacities and limitations of the several steps in the purification processes and with the Oshkosh experience and experimental work as a further guide. At Neenah it was also decided to add softening to filtration. Lake Winnebago water has an average hardness of about 9 grains per gallon. The plant construction involved the rehabilitation and enlargement of the pump pit in the existing power plant building. The new filtration, softening, taste and odor removal plant was housed in a separate structure immediately adjoining the old plant.

Although the use of the hard well water supply at Neenah averaged only approximately 500,000 gallons per day, it was decided to build the new plant so that when operating at normal water works



1, Exterior Filter Plant—Neenah, Wisconsin
2, View of Operating Floor

rating of 2 gallons per minute per square foot of filter surface capacity of 2 million gallons daily would be available. When operated at the rate of 3 gallons per square foot per minute which is practicable

with excess lime treated well settled water the capacity would be 3 million gallons daily. The plant throughout is designed so that this higher rating can be maintained continuously if desired.

The various steps in the new plant include the following arranged in the order of sequence:—

1. Low lift pumping.
2. Chemical feeding in a flash mixing basin.
3. Slow mixing.
4. Coagulation and settling.
5. Filtration through mechanical rapid sand filters.
6. Filtration through granular carbon filters.
7. Storage in clear water reservoirs.
8. High lift pumping to an elevated tank and the distribution system.

The low lift pumping equipment consists of three units rated respectively at 1–1.0 and 2–2.0 m.g.d. These units take suction from a well located on the lake side of the plant. To this well are connected two intakes, one an old 12-inch cast-iron intake extending directly out into Lake Winnebago, a distance of approximately 500 feet, and the second a new 16-inch intake extending across a park into the Fox River at a location a few hundred feet below the point where the Fox River flows out of Lake Winnebago. This location was selected for the new intake on account of the lesser difficulty with ice in the river, which, due to its velocity, normally is open at all seasons and because this location involved a minimum of marine construction with its construction and maintenance hazards. The new intake is in approximately 6 feet of water.

The flash mixer consists of a motor driven vertical shaft propeller type agitator installed in a small compartment at the entrance of the basins which provide both the slow mixing and coagulation basin periods. The flash period is approximately five minutes at rated plant capacity.

A slow mixing period of sixty minutes is provided. During this time the water is agitated by motor driven paddle flocculators, the speed of which is approximately $1\frac{1}{2}$ feet per second at the periphery of the wheels. The flocculators are in a separate compartment located between the two coagulating and settling basins. There are 4 wheels in this basin, each with a diameter of 11 feet and a length of 11 feet.

From the flocculating chamber, the water passes to either or both

of two coagulating settling basins; each basin is 26.5 feet by 70 feet with a depth of 14 feet. The overall detention in the two basins is 4¾ hours at plant rating. The flow through the basins is at a velocity of 3 inches per minute. Entrance to the basins is behind wood baffles consisting of 2 x 8-inch planks with a 1-inch clear space between adjacent planks to secure uniform distribution throughout the cross section of the basins.

At the outlet of the settling basin and separated from the settling compartment by a tight wood partition is the recarbonation basin. This basin provides a retention period of 30 minutes. CO_2 is supplied from oil burners under the heating boiler. Distribution to the water is through a grillage of ¾-inch steel pipe spaced on 12-inch centers with $\frac{3}{32}$-inch holes on 6-inch centers. Two oil burners are provided, the larger burner designed to burn four gallons of oil per hour will be primarily used for heating. It is automatic and is thermostatically controlled. The smaller one, designed to normally operate at 1½ gallons per hour combustion rate, is installed in a smaller combustion chamber inside the main boiler setting. This burner will be manually operated with combustion at the rate necessary to furnish the CO_2 required by the softening rate. The CO_2 gas is taken from the boiler flue, scrubbed, cooled, purified and compressed to about 6 pounds pressure which is necessary to force it upward through the depth of water in the carbonating basin.

The outlet from the carbonating basin to the filter is over a weir. The filters are three in number, each having a sand area of 234 square feet, which at the usual water works rating gives a total capacity of 2 m.g.d. The underdrains are perforated cast iron pipe 2 inches in diameter, with ⅜-inch holes drilled on the bottoms at 6-inch centers. The gravel consists of 5 layers with a total thickness of 24 inches, graded from a maximum of 2½ inches to 1½ inches in the bottom layer to torpedo sand at the top. On top of this gravel there is a sand layer specified as 30 inches in depth with an effective size of from 35 mm. to 40 mm., and a uniformity coefficient of from 1.25 to 1.50. There are 2 wash troughs in each filter. Wash troughs are of concrete cast in place designed to carry away a 36-inch rise washwater rate. Dirty wash water is returned to the lake.

The effluent from sand filters passes to two carbon filters each 11 feet 6 inches x 20 feet 3 inches in plan. These filters have manually operated valves. The granular carbon filters are of the upward flow type. In the Neenah installation, while in the comparison of

bids on carbon consideration was given to the phenol adsorption capacity, credit for high capacity was only given to the extent of one-half of the excess above a minimum phenol number of five in order to more equitably appraise other factors such as durability, wettability, etc. In placing this carbon, considerable difficulty was experienced with its flotation. This was due to the large amount of air entrained in the pores of the carbon. Efforts were made to dispel the air by forcibly submerging the carbon, by hosing and other similar means, but without success. Finally the filters containing the carbons were heated with live steam to such an extent that the air was driven from the carbon, after which it sank; since that time no difficulties with flotation have been experienced.

From the carbon filters the water passes to the clear water reservoirs. These are in two compartments, one of approximately 150,000 gallons capacity being located directly under the filters with a separate rectangular basin outside and to the south of the plant proper with an additional capacity of 850,000 gallons.

The high service pumps are 4 in number, having capacities respectively of 1.2, 1.85, 1.8 and 2.0 m.g.d. These discharge to the distribution system and to an elevated tank of 600,000 gallons capacity which floats on the system.

The plant has now been in operation for several months under Mr. A. M. Hanson, Chemist, and the general supervision of Mr. W. U. Gallaher, of Appleton. The plant has demonstrated its ability to turn out a water having a hardness of from three to four grains per gallon, clear, sparkling, tasteless and odorless, with the exception of a brief period when difficulties were experienced with the CO_2 oil burner combustion.

The total cost of this plant was $145,807.11, distributed as follows:

General construction	$84,330.75
Intake Line	13,917.39
C. I. Pipe & Specials	6,127.92
Pumping Equipment	2,287.00
Mixing Equipment	2,795.00
Clarifier Equipment	4,770.00
Filter Equipment including chemical feed	29,464.00
Granulated Activated Carbon	2,178.05

The Neenah plant is operated under a Board of Commissioners, for which Mr. F. E. Mace is Superintendent.

CONCLUSION

The problems incident to treating Lake Winnebago water, admittedly one of the most difficult in the country to handle from the standpoint of tastes and odors, have been satisfactorily overcome as evidenced by the operation of the Oshkosh and Neenah plants. No data are at present available from which it is practicable to determine the life of the granular carbon under these auxiliary or reserve operating conditions. The experimental studies did, however, conclusively demonstrate that the life would be very short unless the real work was largely done by powdered carbon. Improving the taste of water as well as other improvements in quality, whether mineral or sanitary, is worth its cost. Bad tasting water frequently drives consumers to the use of waters which while more palatable are less safe. Oshkosh and Neenah are to be congratulated upon their pioneer work in scientifically and economically solving their water supply problems.

The engineering work in connection with the Oshkosh and Neenah improvements has been under the direction of Alvord, Burdick & Howson, consulting engineers, of Chicago, who had associated with them Mr. John R. Baylis and Mr. Charles P. Hoover as consultants.

Discussion by A. E. HINTZ.* Mr. Howson's paper has covered the treatment of Lake Winnebago water very thoroughly and there is little that can be said to add to it.

The water furnished the city prior to 1937, always was accompanied with numerous complaints from the consumers in regards to tastes and odors, particularly throughout the summer and early fall. These complaints became so numerous and persistent by 1934 that very serious thought was given to abandoning the lake supply in favor of a well supply. In fact a geologist was engaged to make a survey on the possibility of such a supply and the quality and quantity of water that might be expected. This report was rather discouraging, both from the quality of the water to be obtained and from a cost point of view.

The next step was to engage expert engineering advice, relative to the treatment of the present supply. After nearly a year of experiments and tests, it was finally decided that carbon treatment was the most economical and practical method to improve the quality of the water insofar as tastes and odors were concerned.

*Manager, Water Department, Oshkosh, Wisc.

In 1936 plans and specifications were drawn up by the engineers to house 4—1 m.g.d. activated granular carbon filters and to add to the present plant such necessary accessories as improved baffling of the sedimentation basins, including both rapid and slow mix equipment, increased and improved methods of feeding activated powdered carbon, floc detectors on each sand filter and a clear well observation light.

A carbon feeder of the gravimetric type was purchased in 1935. This feeder has a rated capacity of feeding 1,200 pounds of carbon per day. With the use of an extension hopper, the feeder can be charged with 750 pounds at one time. Dust-proof motors are provided to operate the feeder. This machine, although not perfect, feeds carbon steadily and accurately. An alarm bell is used to indicate when the feeder is empty or not feeding accurately. It is also equipped with a chart recording instrument, a dust removal device and a mixing pot which prevents free floating carbon in the basins. The cleanliness of the feeder is one of its outstanding features.

The average threshold point number of raw water (hot) is 6 with a maximum of 17 and a minimum of 3. As much as 420 pounds of powdered carbon per million gallons was used in 1937 to reduce the threshold number to 1 (hot). It has been our endeavor to maintain a threshold number of 1 (hot) in the effluent of the sand filters, thereby relieving the granular carbon filters of the increased load.

It was anticipated that the granular carbon filters would be foolproof and leave the effluent entirely free from tastes and odors. Such has not been our experience and it is our belief that the carbon filters are limited in capacity to the amount of tastes and odors they will adsorb at the rate at which they are operated.

The quality of the city water in the past eleven months since the new carbon plant was put in operation is very satisfactory and entirely free from tastes and odors, except for a short period when the raw water carbon demand exceeded the capacity of the powdered carbon feeder and an increased duty was placed upon the granular carbon filters. At that time a slight taste and odor was noticed by a few people whose sense of taste and smell were extremely acute. Although this method of taste and odor control has increased operating costs, it is cheaper than abandoning the present system for a well supply. The open approval of the consumers on the whole justifies the increased cost of operation.

THE HANDLING AND FEEDING OF ACTIVATED CARBON

By J. C. Zufelt

The use of activated carbon for taste and odor removal in water treatment began about 1930. Much has been learned about its properties; much remains to be learned; but one property of carbon about which every user feels he knows all he wants to know is its dusty, black, penetrating dirtiness.

The plant chemist determines how much carbon to use to cope with the current taste and odor problem, and where and in conjunction with what other chemicals to feed it. The plant operator lies awake at night trying to contrive some means of handling the material that will result in a cleaner plant and personnel and prevent hazards of fire and explosion and damage to motors by the dust.

Activated carbon has truly brought in a new era of refinement in water purification results, but has brought with these tremendous improvements in palatability its own problems of feeding and dust nuisance.

It is my intention to briefly review the subject of carbon handling and feeding, chiefly from the standpoint of the physical equipment and handling methods.

Carbon handling and feeding involves bringing the material into the plant and storing it, getting the material into the feed machine (or making a suspension in the case of wet feed), measuring and feeding in correct proportion with some feed device, and conducting the suspension to the point of application.

An important point in dust prevention is the care used in emptying the bags into the feed machine hopper. A good precaution in filling hoppers is to fill them frequently so the carbon does not have to fall so great a distance. Some form of hood over the hopper top which will limit the opening just to permit the bag to enter helps prevent the "bounce" of a cloud of dust into the room as the carbon falls into the hopper. Add to this an air suction in the hood, discharging

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outside or into a vacuum cleaner bag, and much dust will be prevented. In spite of all precautions, however, dust will seep into the room, and the best way to keep it confined is to store the carbon, and charge hoppers, in a room segregated from other storing and feeding rooms.

Where an extension hopper is employed to permit filling from the floor above the feed machine, the connection between the extension hopper and feed machine hopper must be dust tight. If this hopper is scale mounted with a flexible connection to the machine, making it dust tight may be difficult. A canvas sleeve used in our own installation is not entirely satisfactory. We intend to try a rubberized fabric, using a gasket compound to cement it to the metal collars under the clamps. Our hopper is rigid, but the feeder itself is scale mounted. This requires that the $2\frac{1}{2}$-cubic feet hopper, which is part of the machine, must be periodically filled from the rigid storage hopper. Above the canvas sleeve connection is a slide gate to effect this filling. This gate is a sore point in the dust problem. It is a steel plate sliding in felt packing which is supposed to keep dust from coming through, but does not. I think that part of the reason for this is the displacement of air in the machine by the carbon, which results in a pressure which forces the dust out. We plan to place an air vent in the machine hopper which will permit quicker filling and relieve this inside pressure when the carbon comes down. This vent will be piped into the extension hopper above the carbon level, so dust blown out with this current of air will not be forced out into the room. Even with this help, the gate itself will have to be improved.

There are numerous machines on the market for feeding carbon. Some of these have been designed primarily for carbon, and some adapted by the manufacturers to its use. Most of these machines feed with a reasonable degree of accuracy, as long as the carbon flows without interruption to the feeding or proportioning mechanism of the machine. Carbons, however, have a tendency to arch in the hoppers more persistently than alum, so the shape and diameter of the hopper, and the nature of the agitating device to keep it flowing to the feed mechanism, are important. Too abrupt a slope of the bottom cone of the feed hopper should be avoided. The hopper should be large enough in diameter in the vertical portion, and have some form of rotating blades extending somewhat above the hopper cone into the vertical portion to break down arching. One manufacturer employs an ingenious device which flexes the hopper slightly

on alternate diameters, thus breaking down arching. Another employs an electric vibrator which is quite successful. Several plant superintendents have made "thumping devices" automatically to pound on the outside of the hopper to help keep the carbon moving. Even with the latter device, in our own experience, it was still very necessary to have an adequate agitator inside the hopper.

The point at which the carbon drops from the feeding mechanism into a mixing bowl or box to form the suspension is another source of dust. The use of a water ejector in the feed line just below this bowl will create some suction, and therefore a slight current of air into the bowl, which helps keep dust from the room. The design of some of the feeders, which are entirely enclosed by metal cases, leaving only the motors outside, helps to keep the dust in. But the best of these are none too successful. Complete segregation of carbon machines in tight rooms away from the operating floor and other feeders, is the best solution of the dust menace.

The feed line, or pipe carrying the suspension from the machine to point of application, should be as short and direct as possible, provision being made for cleaning out carbon which may settle and cause clogging. It should be on a continuous down grade away from the machine to prevent clogging, and an ample flow of water should be provided to carry the carbon away rapidly enough to prevent settlement in the line.

As to point of feed, many plants feed their carbon into the raw water with or close to the alum, thus giving the carbon the longest possible adsorption time, and not unduly overloading the filters with carbon as occurs when it is applied just ahead of the filters. However, most of the plants have their feed piping so arranged that they can feed directly ahead of the filters in case of an emergency.

The plant at Hammond, Indiana, is designed and built primarily to remove taste and odor by activated carbon. Its bacteria removing load is far greater than that of plants farther north on the lake, but its taste and odor problem is so tremendous that it far overshadows the former in cost of treatment. Hammond has completely segregated its carbon storage and feeding facilities from the rest of its chemical storage and feeding equipment, and I commend this method to all engineers designing new plants. Hammond uses in the neighborhood of 600,000 pounds of carbon per year, and it is easy to see how this quantity of carbon used in a plant of 20 m.g.d. capacity could cause a tremendous dust problem if drastic steps were not taken to prevent it. The carbon in bags is brought into a store

room on the floor above the chemical feed room. This room is shut off from the rest of the chemical store room by a tight fitting, weather-stripped door, equipped with a refrigerator latch to wedge it tightly shut. From this room a door opens into a small room directly above the two Bacharach dry feeders, their hopper opening through the floor into this room. The tops of these hoppers are fitted with hoods having openings that will just fit the top of a carbon bag. The hood has a small vacuum cleaner attached to it which draws in air while the bag is being emptied, preventing to a great extent the escape of dust into the room. Here again, in spite of all precautions, the room is dusty, but the dust is confined to that room. The carbon feed machines are also located in a separate, dust-tight room, sealed off from the rest of the chemical feed room by a weather-stripped, refrigerator latched door. This complete segregation is in my opinion the best arrangement for keeping carbon dust out of the plant.

Evanston, Illinois, uses an Omega feeder. The machine is located in the chemical storage room away from other feed machines and the operating floor. There is no extension hopper, and the operators have developed a technique of dumping the bags into the machine, from a step ladder, that is surprisingly free from dust.

Wilmette's Bacharach feeders are located in the feed room with the alum machines. They have a platform over the machines for emptying bags into the machine hoppers. The bags are raised to this platform on a small electric elevator. Care in emptying, and a hood with bag-size opening help somewhat, but dust is still plentiful. The feed room is away from the operating floor so dust is not evident there.

Highland Park uses an Omega feeder which is situated in the chemical storage room away from other feed machines and the filter floor. Here the carbon bags are emptied one at a time as needed into a box beside the machine, from which the carbon is transferred to the machine hopper with a metal scoop. An ingenious system of numbering the carbon bags in storage with chalk, and checking the box contents at each shift of operators, enables a close check to be made on the quantity fed.

Winnetka has built a wet feed machine that has been very successful. A heavy sludge of carbon is made by placing two bags or 70 pounds of carbon in a barrel and adding 40 gallons of water. This sludge is drained into a 125 gallon tank and made up to 125 gallons with water. In the top of this solution tank is a constant level box

consisting of a metal pail with the feed pipe extending downward from its bottom to a point on the floor below, where it terminates in an orifice nozzle. A number of these nozzles are on hand, each having an orifice of a size to permit a given desired rate of feed of the suspension. The nozzle in use discharges into a box from which the suspension passes to the point of feed. This affords a point where the feed can be visually inspected so as to be sure it is flowing properly. Such inspection is necessary because clogging of the nozzle occasionally occurs. A pipe leads from the bottom of the solution tank to the suction of a small electric pump which discharges back into the top of the constant level box, all excess of suspension not passing through to the orifice overflowing back into the tank. This recirculation provides excellent mixing to keep the carbon in suspension. All parts of this pump are of bronze to prevent corrosion. An agitator run by a small motor is also provided to stir the suspension in the tank. This tank is located in the chemical storage room so the dust incidental to making the suspension is confined to that room.

Lake Forest uses the Syntron vibrating type of feeder, placed in the alum store room. The feed trough of this machine is covered, but dumping the bags into the hopper results in considerable dust.

Oshkosh uses the Omega gravimetric type of feeder. This machine is filled from the chemical store room on the floor above the feed machine. The top of the hopper in this room is enclosed in a cabinet, in which several unopened carbon bags can be placed. The bags can therefore be opened and emptied entirely within this cabinet, only a small door being opened into the room, through which the operator works. A current of air into this cabinet is induced by a water ejector or aspirator which draws the dust through sheet metal pipe and discharges it with the ejector water into one of the basins. The carbon from the feeder is discharged into the mixing bowl of the machine under water. This installation is the most dust free of any I have seen. The feed machine is on the main floor of the plant, but no dust is apparent around it.

The chief conclusion to draw from the material here presented is that the handling and feeding of carbon largely remains a dirty business. By segregating the equipment from other parts of the plants, by carefully handling the carbon, and by seeking in every way possible to make feeders dust tight, the dust problem can be reduced somewhat, and the parts of the plant frequented by the public kept in a presentable appearance.

PROBLEMS ENCOUNTERED IN LAYING MAINS

By Laurence W. Anderson

We are of the opinion that we are in the business of selling water, so we must be willing to give the same service or better, than any private company selling a commodity, without any or as little interruption of service as possible.

TEMPORARY SERVICE

The first problem I will touch upon will be temporary service. A great many private business institutions which include manufacturing plants, dairies, beauty parlors, hospitals, doctors, dentists, and schools, are so dependent upon water that they in some cases would have to close down entirely or it would be unhealthy to operate. There have been times when private services have broken and buildings and institutions have called upon the water department for a temporary supply. Whenever possible a hose line is run from the nearest hydrant and connected at the meter. Hose have been run from building to building. In such cases the meters were removed so one consumer would not be charged for another's consumption.

On one occasion some repair work was necessary on a main abutting one of the large dairy companies of the city. This company, you can realize, could not operate without water. The consumption was so great and the hose line of such a length and size as to be inadequate. The Milwaukee Fire Department was called upon for a pumper to boost the pressure and quantity, which they furnished very willingly.

The Milwaukee Fire Department has helped the Water Department on a number of occasions.

In 1932, a cross-connection was made in Arnauld Ave. between the old 30-inch feeder main, which supplied the City of West Allis, Village of West Milwaukee, and the southwest section of the City of

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A paper presented at the meeting of the Wisconsin Section at Green Bay, November, 1937, by Laurence W. Anderson, Field Engineer, Water Department, Milwaukee, Wisconsin.

Milwaukee, and a new 36-inch feeder main laid in this vicinity for a dual supply to the area mentioned above.

The City of West Allis, Village of West Milwaukee, and the southwest section of the city were on the so-called high service. This 30-inch feeder main was the only supply outside of a 12-inch main which would be wholly inadequate.

The Fire Department supplied two pumpers, with a third in readiness, which pumped from hydrants on the border line in the low service area to hydrants in the high service and maintained pressures continuously for a period of 3 days.

In the past year, the Wisconsin Highway Commission proceeded with a grade separation project on Chase Avenue. The entire street and roadway were shifted some thirty feet south and the grade changed. This meant relocating the service and meter to the railroad yards and round house. The old fittings and meter were to be reset. The railroad yards and round house did have two supplies and an elevated storage tank into which both services were connected. They were not valved off here however, but did have an automatic valve on top of the tank, which was closed. This elevated tank supplied water to the round house and the various stand-pipes by gravity. The tank is located in a very inconvenient place. A hose had to be laid down a fifty foot bluff, across the Kinnickinnic River, under approximately ten tracks, into the top of the tank, a distance of about eight hundred feet. The normal pressure of the hydrant could not maintain a sufficient height in the tank. Here again a Fire Department pumper was called upon.

During the year of 1936 a total of 64 large consumers were supplied and 19,650 feet of $2\frac{1}{2}$-inch hose laid for temporary service while street mains or service pipes were temporarily out of service on account of repairs or otherwise.

DAMAGE CASES

Damage cases often occur. For example, at the time a new 16-inch water main was laid in Green Bay Ave. to supplant the 6-inch water main, the filling of the new line and the reconnection of the services were to be done in one afternoon. Late in the afternoon a bad leak was observed, which later was found to be due to a cracked pipe, and it was decided to make the necessary repairs immediately. Unknowingly, the plumber, who was reconnecting the services, warned the residents in a duplex flat to leave their faucets open as the repairs

would not be made until late that evening. The repairs were completed about eight o'clock in the evening, and the line filled. Both tenants of the flat had opened their faucets and left the house for the evening. Returning about one A.M. they found their house flooded. The damage here amounted to between $3,000 and $4,000 and was finally settled by the contractor's insurance company.

Prior to the repaving of Milwaukee Street in 1935, an 8 and a 12-inch water main were laid to supplant the 20-inch main, which was to remain solely as a feeder main. During this time we were so unfortunate as to have a rainy period. It happened that the contractor had cut several holes through the retaining walls for setting additional hydrants under the so-called hollow sidewalks. Merchandise and machinery were stored in these various basements. The floors of these basements being lower than the sewer in the street, and none of the buildings being equipped with sewer pumps, it can be readily seen we had a number of indoor wading pools. The portable pumps of the water department were busy day and night. In some instances, we were fortunate enough to have elevator pits to use for sumps.

SOIL CORROSION

I would like to touch upon an experiment for neutralizing soil, which has been repeated, and because of which we do not expect any further trouble. During the year of 1930, a Class "H" cast-iron fire main was laid for the Milwaukee Fire Department in a vacated slip of the South Menomonee Canal, in the yards of the Northwestern Fuel Co.

This line is dry during the winter months, but filled during the rest of the year without pressure, except during a fire. During a pressure test in 1935 a break occurred. Upon being exposed, the pipe and fittings were found to be extremely corroded. The bolts on the valves and hydrants were corroded through. Upon investigation the soil was found to be excessively acid, caused by a leak in a drain of waste acid liquors from the National Enameling and Stamping Co., adjacent to the pipe line. This leak has since been repaired.

To neutralize the acid condition of the soil it was decided by Mr. Heisig, Chief Chemist of the Milwaukee Sewerage Commission, who was consulted, to remove the soil to a distance of one foot to the sides and below the pipe, and to backfill with soil of a mixture of clay and sand in one foot layers with a layer of two inches of spent lime

between them. This spent lime, a waste by-product from the manufacture of acetylene gas, was obtained free of charge. No further trouble is anticipated with this line in the future.

In this last summer a new 12-inch water main had to be laid to supplant a 12-inch main in Greves St., in which a great number of leaks and breaks had taken place in the last year, and which was found to be considerably corroded. The original line was laid in 1903 through an area in which the soil was fill and cinders. After a period of thirty-four years (or a third of its normal expected life) this line had to be replaced.

This pipe probably could have been continually repaired, and given longer service. It served a manufacturing area where a number of large consumers were located. These manufacturing plants were so situated that it was impossible to give any temporary service while repairs were to be made. The latter two reasons bore the greatest weight in taking the move we did.

This main was laid in a narrow street with a narrow roadway and sidewalk. Already a 42-inch by 75-inch box sewer, a 36-inch brick sewer, a 36-inch intercepting sewer, a conduit and a 12-inch water main which could not be removed had been laid beneath it.

In constructing this line, the excavation was carried to one foot below the pipe and one foot to both sides. The excavated material, which was mostly cinders and ash fill, was removed from the work. In Milwaukee, where a pavement has been cut through and an excavation takes place, backfill must be with gravel. Backfilling of this trench was somewhat similar to the backfilling over the fire main mentioned before, starting at the bottom with a 2-inch layer of spent lime and a foot of gravel placed alternately to the surface. This was done in hopes of neutralizing the acid condition of the soil adjacent to the water pipe.

TESTING NEW MAINS

We have been testing mains of 20-inch or larger shortly after they have been laid. The pressure test has been applied immediately. The meter test is usually run about two weeks later as jointing compounds are used exclusively.

We were able to isolate a 20-inch water main one-half of a mile long which had just been laid, and place a meter on the inlet side. This meter was read every day for thirty-seven days. These readings were plotted on graph paper giving us a general leakage curve which

resembles a parabola, from which a daily leakage curve was completed. Using the allowable leakage as given in the City of Milwaukee Specifications, which is one-half gallon per day per lineal foot of pipe joint, we are able to derive a figure for calculating the leakage which enables us to test a line without waiting any set number of days.

These figures are as follows:

1st	day	15.2	Times	allowable	leakage
2nd	"	8.7	"	"	"
3rd	"	5.0	"	"	"
4th	"	3.3	"	"	"
5th	"	2.0	"	"	"
6th	"	1.6	"	"	"
7th	"	1.3	"	"	"
8th	"	1.2	"	"	"
9th	"	1.1	"	"	"
10th	"	1.0	"	"	"

Mains are sterilized whenever possible. This phase of construction is under the jurisdiction of our chemist. Liquid chlorine is used exclusively. A portable chlorinator is used in sterilizing small mains; for large mains we use the old fashioned method of placing a tank of chlorine upon a scale and gaging the amount of chlorine with the time of filling. The amount of chlorine given the water is approximately 100 to 500 parts per million, depending upon conditions. The chlorinated water is allowed to stand for at least twenty-four hours. The line is then drained if possible and refilled with fresh water. If the line cannot be drained, the chlorinated water is displaced until pure water is wholly within the line.

EXPERIENCES WITH WATER METERS

By A. J. Gurck

(*A Translation*)

The introduction of water meters has a two-fold object: (1) Fair and exact determination of the consumer's water account. (2) Suppression of waste.

So far as the first point is concerned, it is admitted that we have in our country both advocates and opponents of universal metering. It is a fact that in many countries, even in America with its almost unlimited supplies of water, the water-meter is steadily gaining in favor. The meter is on the march and nothing can stop it. Whether or not this opinion is correct is outside the scope of our present subject and therefore I shall not discuss it. It would certainly be interesting and useful for the leaders of the Netherland water supplies that this question should be studied from both sides and discussed at one of our meetings.

Regarding the second point, the limitation of waste, it is obvious from the accompanying graph (fig. 1) of water consumption in the 's-Gravenhage district that the per capita consumption has sharply declined following the introduction of the so-called control meter system in 1898. In this connection it must also be remembered that the development of sanitary plumbing in the course of the years has caused an increased use of water; I am thinking here especially of the multiplication of water closets and baths. When, notwithstanding, the per capita daily consumption has declined from over 100 liters (26 gal.) in 1898 to less than 70 (18 gal.) at present, it must be concluded that the waste of water has been reduced in even greater measure than would at first sight appear from the per capita consumption.

A paper presented at the general meeting of the Association of Water Supply Officials in Holland, May 21, 1937, by A. J. Gurck, Chief Engineer and Departmental Head of the Hague Dune Water Supply, Printed here by permission of the Secretary. Translation from "Water" (Neth.) by Frank Hannan.

CHOICE OF METER WITH REGARD TO ACCURACY

It is, in general, advantageous to select a meter of the smallest bore possible for any given purpose.

In the first place the sensitivity of the smaller meter is greater than that of a larger one, especially in the case of velocity meters. In the second place the price of the smaller meter is less than that of the larger. The first point is of especial importance in view of small drafts and in connection with leaky pipes or fixtures.

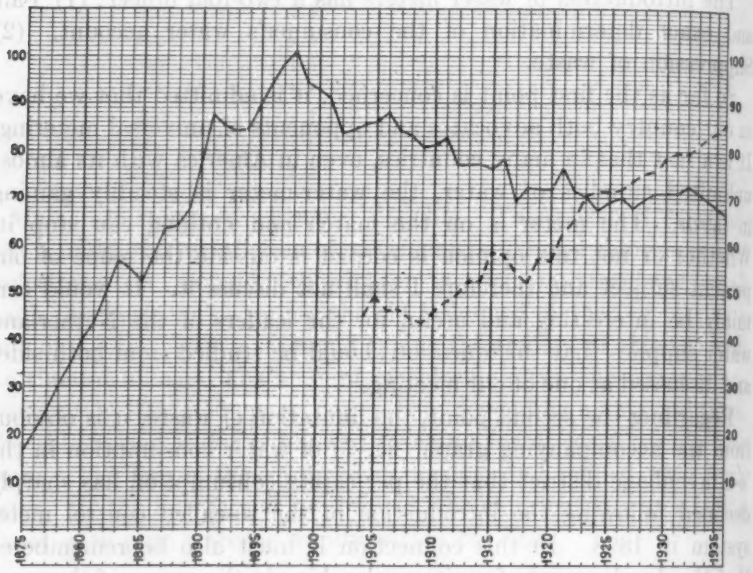


FIG. 1. Solid line indicates daily per capita consumption in liters. Dotted line indicates percentage of total pumpage registered by meters.

In almost all cases in homes, factories, etc., the greater part of the water will be drawn at a rate greater than 300 liters an hour (1.32 gal. per minute), at which correct registration by good meters of capacities up to 20 cubic meters an hour (88 g.p.m.) is assured. During these drafts the leaks will of necessity be fully registered also. But the time during which these drafts take place is very often short. In a house with a monthly consumption of, for example, 15 cubic meters (4000 gal.) the average daily consumption is 500 liters (132 gal.) which corresponds to a time of hardly one hour per day. Now if this house has an individual connection with the

supply, the danger must follow that for over 23 hours in the 24 any leak that may exist will fail to be registered. In this connection too we have to think of fixtures with a small continuous water demand, for instance, refrigerators. The water consumption of these is in many cases less than 20 liters an hour (.09 g.p.m.) which corresponds to about 15 cubic meters (4000 gal.) a month. It is also well known that photographers and fish dealers often keep a small flow running.

Nearly all 3-cubic meter (3 cu.m. per hour = 13 g.p.m.) velocity type meters at present in use will fail altogether or in part to register flows of less than 20 liters an hour. To obtain correct registration in such cases, it is advisable to employ a volume-meter. Here let it be observed that it is dangerous to use volume-meters for premises with fire hydrants, if the hydrant supply is on the same meter, because they sometimes stick and might interfere with the supply in case of a fire. In these cases the hydrant supply will often require a larger meter separate from the rest of the establishment, and in that case a volume meter would be suitable for correct registration (of the regular supply). Volume-meters in general have the disadvantage that they go out of order more easily than velocity meters under sudden increases of pressure and may choke up almost completely. Moreover they are more liable to stick when foreign substances, such as sand, get into them, or from corrosion. It is therefore necessary for volume meters to be fitted on both the upstream and the downstream sides with strainers of not too coarse a mesh. The modern construction of the measuring chamber with ebonite walls of extreme smoothness has eliminated altogether the danger of corrosion and probably for the most part that of lime deposits.

PERMISSIBLE LOADS

The wear on a water meter is not directly proportional to the quantity of water which it passes. It is known for instance that, in meters of velocity type, when the flow is small the runner is supported by the toe. As the flow increases, however, the runner experiences an upward thrust, the magnitude of which is such that, speaking in a very general way, when the flow exceeds 10 per cent of the meter's rated capacity, the upward thrust will exceed the weight of the runner in the water and has to be taken care of. This is done either by a shoulder on the shaft of the runner acting against

the bearing in the floor of the mechanism compartment or else by a special thrust bearing at the shaft's upper end. The wear on the toe will accordingly be greater for a given quantity of water when it has passed through the meter slowly than when it has been drawn off rapidly. On the other hand when the quantity flowing through the meter exceeds one-half its rated capacity, the wear on the rest of the mechanism rapidly increases with the flow.

Here among other matters I may mention that for several successive years three 3-cubic-meter (13 g.p.m.) meters in series were installed on the water supply of a large public lavatory at Scheveningen. During four months of each year there was a nearly constant load of about 1 cubic meter an hour (4.4 g.p.m.) or 25 cubic meters (6600 gal.) a day. No wear of any consequence could be detected on any of these meters. In earlier years, in view of the large daily load, a so-called $1\frac{1}{2}$-inch meter had been installed at the same place. Taking one thing with another, it would seem that it is a difficult matter to determine with any approach to accuracy the permissible load for any given meter. Experience has, however, established certain guiding principles for the cases of most frequent occurrence.

For example, it is common knowledge that in the past it was laid down in some meter lists, of both velocity and volume types, that the rated (hourly) capacity of the meter under a head of 10 meters (33 feet) should be regarded as the maximum daily load. This accordingly means that for 3-, 5-, 7-, 10- and 20-cubic meter meters (13-, 22-, 31-, 44- and 88-g.p.m.), respectively, the maximum daily load should be 3, 5, 7, 10 and 20 cubic meters (790, 1320, 1850, 2640 and 5280 gallons). For the conditions normally encountered at The Hague and for meters of good construction and not more than 25 years old, these figures are regarded as on the safe side. In the latest German lists, the permissible monthly loads for the 3-, 5-, 7-, 10- and 20-cubic meter meters are respectively given as 90, 150, 210, 300 and 600 cubic meters (24,000, 40,000, 55,000, 80,000 and 160,000 gal.) and the permissible daily loads as 6, 10, 14, 20 and 40 cubic meters (1600, 2600, 3700, 5300 and 10,600 gal.). The permissible peak loads are given as 3, 5, 7, 10 and 20 cubic meters per hour. These monthly and daily loads are on the safe side for meters of modern make under conditions usually prevailing. The peak loads seem to me high. It seems to me safer practice to fix as maximum peak loads 2.1, 3.5, 5, 7 and 14 cubic meters per hour (9, 15, 22, 31, 62 g.p.m.) respectively: that is to say,

the capacity under 5 meters (16.4 feet) head. In actual practice the peak load would seem as a rule to be still lower because the permissible monthly and daily loads on a meter are more often exceeded than is the load at 5-meter head.

Caution is necessary in the case of premises where the water consumed has to be pumped into an air-pressure vessel or a high level tank. Although in these cases according to the experiments of the A.V.W.L. the peak load on the meter is but slightly increased as compared with supplies without any booster installation, yet experience teaches that the water-fitter is inclined to select a pump of capacity several times greater than is necessary or desirable. The

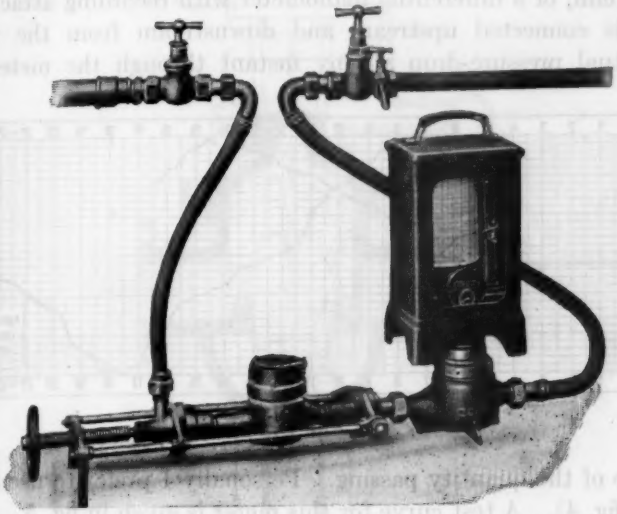


FIG. 2

layman imagines that ample reserve capacity can do no harm and is the part of safety for himself in view of possible complaints of his installation being too small. Moreover the difference in price for pump and motor between a set of capacity of 3 cubic meters per hour (13 g.p.m.) and one of 15 cubic meters per hour (66 g.p.m.) is small. It is therefore necessary where booster installations are in use to limit the size of pump to be installed, in order to protect the water-meter.

In order to gain some insight into the details of the water consumption on any premises it is desirable to have available instruments which will record the rate of consumption on a chart. The

best apparatus in my opinion for this purpose is the volume-type meter with registering attachment (the "trouble-chaser" (Schadensucher)) (fig. 2). On the chart (fig. 3), not only is the total consumption registered, but at the same time the load on the meter at any given instant can be read off without difficulty from the slope of the curve. When the recording meter is installed in series with the meter actually on the premises, one has a perfect control on the indications of the latter.

It must be admitted that the magnitude of drafts of very short duration cannot be read with accuracy from the chart. If there be need to know these quantities exactly, use can be made, as is done in Amsterdam, of a differential manometer with recording attachment which is connected upstream and downstream from the meter. The actual pressure-drop at any instant through the meter is a

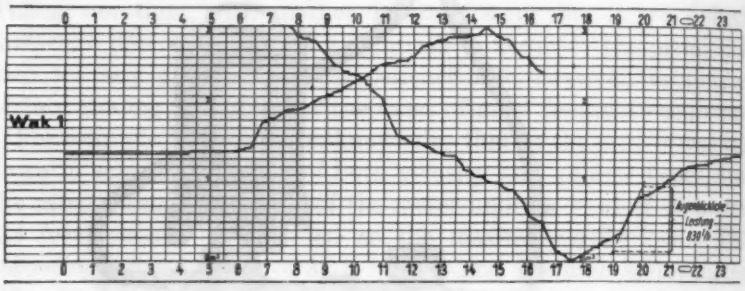


FIG. 3

measure of the quantity passing. Personally I prefer to use a float meter (fig. 4). A test curve for this meter is given in fig. 5. Fig. 6 reproduces a chart as produced by the meter.

As regards the selection of the size of meter for new premises, I may say that after one has gained some experience a good selection can as a rule be made after a few small calculations and "by hunch." One must not be worried when it happens that the meter chosen is too small and has to be replaced by a larger one.

For fire hydrants, among other things, it is necessary to know the size of the outlets. In this case reckon 6 cubic meters an hour for each square centimeter of opening (170 g.p.m. per sq. inch). If several hydrants have been installed on the same premises it is a practical impossibility to use them all at once. In many cases it is safe to assume that only 2 or 3 hydrants will be in use together.

It is probably superfluous in this connection to take account any longer of rules formerly regarded as established, such as "the meter of the same size as the pipe on which it is fitted," or "the meter one size smaller than the pipe on which it is fitted."

It is quite possible, for example, that a 10- or 20-cubic-meter meter must be installed on a 1-inch pipe, although it may happen

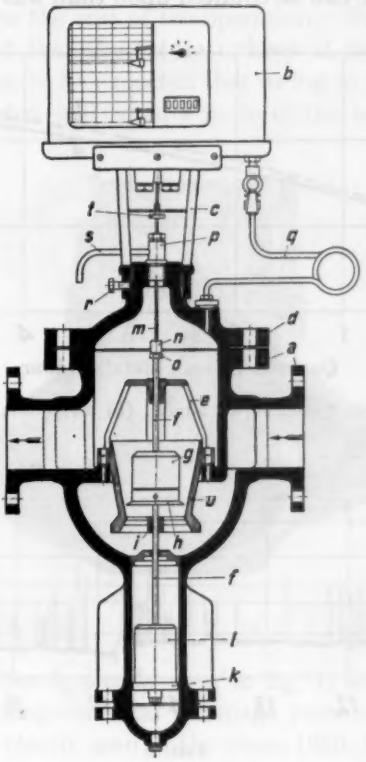


FIG. 4

that on a 1½-inch connection a 5- or 7-cubic-meter meter will be correct.

Here too let it be observed that the old-style meters, such as those with worm transmission had a notably smaller permissible load factor than modern meters. Hence it is that it has been possible in the course of the last 20 years very largely to replace large meters with smaller ones.

REJECTION OF FAULTY METERS

In recent years the percentage by which water meters are annually written down in The Hague has been 6 per cent, which corresponds to a useful life period of about 17 years. Experience has shown that for meters of older types this percentage is too low rather than too high. My expectation is that from now on a longer period of useful life can be counted upon than was formerly the case.

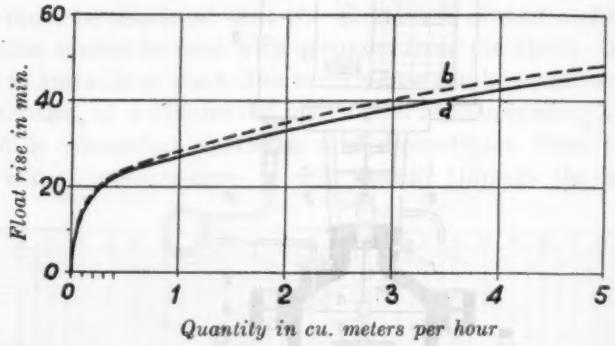


FIG. 5. (*a*) WITH INCREASING FLOW; (*b*) WITH DECREASING FLOW

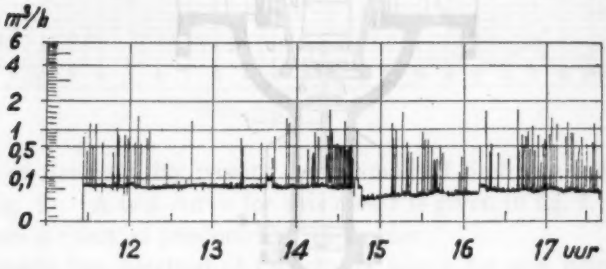


FIG. 6

The construction of the latest types of meters is, for example, markedly superior to that of older types, and, what is of the greatest significance, the quality of the material for the interior of the meter has been brought to a higher level. Owing to all these improvements, the sensitivity of the meters has considerably increased, the curve of error improved, and, a very important point, the period during which accuracy of registration is maintained (Meszdauerhaftigkeit) has been greatly prolonged.

Further it is a matter of common knowledge that the price of new meters in Holland, because of the competition of several foreign countries, has been low for several years.

Under these circumstances it is highly advisable to get rid of all faulty, antiquated meters and replace them by new ones. The proceeds from the sale of the old meters, and the cessation of the continual repair work on them after each periodical inspection will considerably reduce the cost of the operation. Further it should be taken into account that the future upkeep of the new meters will be lower. It is also to be expected that owing to their greater sensitivity the new meters will register more of the water. The results

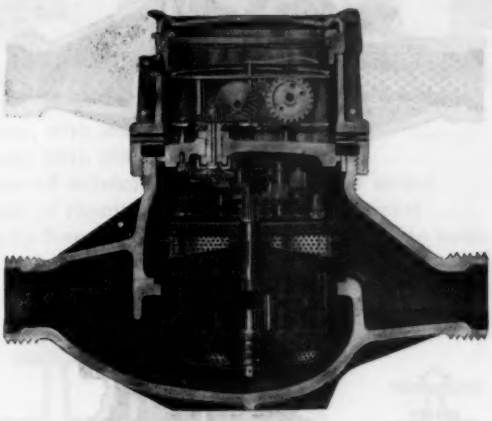


FIG. 7

of this are, for instance, clearly seen in fig. 1, where in the curve showing the percentage of total pumpage recorded on the meters, a sharp increase is clearly seen in the years 1920–1924 which can be regarded as mainly due to the replacement of poor meters by better ones.

In replacing old meters by new, it is further of primary importance to investigate to what extent large meters can be replaced by smaller, and where a velocity-meter can be replaced by a modern volume-meter. As has already been mentioned, the meters of "even-bore" "of prehistoric times" had a smaller capacity than would now be the case. Before 1920 there were in The Hague, for example, still several 1½-inch meters in use which at 10 meters (33 feet) head had

capacities varying from 14 to 17 cubic meters per hour (62-75 g.p.m.). When it is further considered that these meters could only be given a much smaller load in proportion to their capacity, it is quite evident that in almost all cases a large meter can give place to a smaller one. As an example, I can offer The Hague, where in 1921, with a population of about 360,000, the number of meters of $\frac{3}{4}$ inch size or greater was 11.6 per cent of the total number of meters.

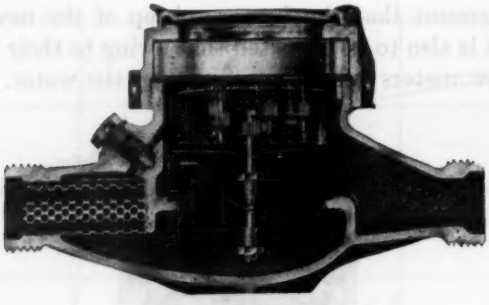


FIG. 8

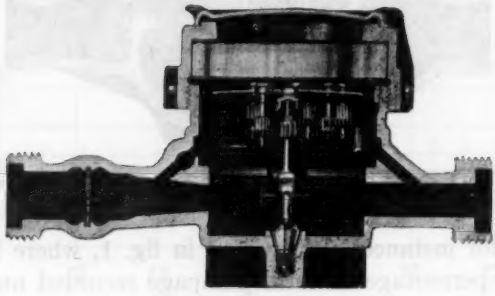
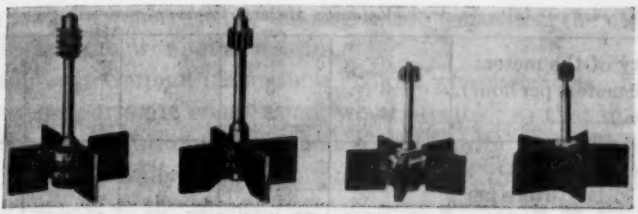


FIG. 9

Now, for a population of about 490,000, this percentage has fallen to about 2.2.

To give an example of the great advances made in meter construction in recent years, some of the new German Standard Meters are illustrated in cross-section. Fig. 7 illustrates a modern volume type meter, with non-submerged mechanism; Fig. 8 illustrates a modern multi-jet meter with submerged mechanism; Fig. 9 illustrates a modern single-jet meter.

Fig. 10 shows the development in the construction of the runner. Here I may mention that the runner of a standard 3-cubic-meter meter (13-g.p.m.) weighs in water just over 6 grams or not much over one-fifth of an ounce, and that runners have been constructed in which both shaft and pinion are made of ebonite (spec. gr. 1.15) and which weigh in water something over a gram.



1877 1903 1906 1928

1877—runner, with worm gear of red brass ..... 33.7 grams
1903—runner, with pinion of red brass ..... 28.4 "
1906—runner of celluloid, shaft and pinion of nickel ..... 11.2 "
1928—runner of ebonite, shaft and pinion of nickel ..... 5.7 "
Weights are for 7-cu. m. (31-g.p.m.) meter, weighed in water.

FIG. 10

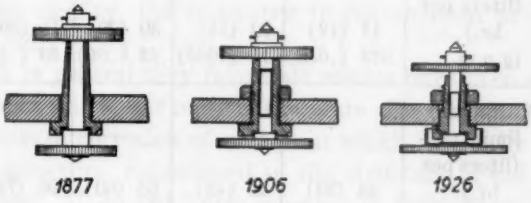


FIG. 11

Fig. 11 illustrates the evolution in the construction of the so-called "conical bushing" (corresponds to the stuffing box of American meters.—Ed.) which is now no longer conical.

Here let it be said that so far as sensitivity is concerned, requirements more exacting than those laid down in the German Standard Din 3260 should be met. In the accompanying table 1 are reproduced some figures from the Din specification. Beside them in parentheses are the limiting figures to which good new meters should certainly conform.

MATERIAL

Speaking generally, brass has not proved uniformly satisfactory at The Hague. The chief difficulty with brass seems to be corrosion, which makes itself specially felt in the case of small articles, nuts and screws. There have been also, however, general complaints of

TABLE 1

Velocity Meters

Capacity of the meter: (cubic meters per hour). (*g.p.m.*)		3 *13*	5 *22*	7 *31*	10 *44*	20 *88*
Mechanism non-submerged	Start at: (liters per hr.)	18 (15)	25 (20)	35 (30)	50 (40)	90 (50)
	(*g.p.m.*)	*.08 (.066)*	*.11 (.09)*	*.15 (.13)*	*.22 (.18)*	*.40 (.22)*
	Within the limit*: (liters per hr.)	40 (35)	60 (50)	80 (65)	110 (90)	185 (150)
	(*g.p.m.*)	*.18 (.15)*	*.26 (.22)*	*.35 (.29)*	*.48 (.40)*	*.81 (.66)*
Mechanism submerged	Start at: (liters per hr.)	17 (12)	22 (15)	30 (20)	45 (30)	70 (40)
	(*g.p.m.*)	*.075 (.053)*	*.10 (.066)*	*.13 (.09)*	*.20 (.13)*	*.31 (.18)*
	Within the limit*: (liters per hr.)	35 (30)	50 (45)	65 (60)	90 (75)	150 (125)
	(*g.p.m.*)	*.15 (.13)*	*.22 (.20)*	*.29 (.26)*	*.40 (.33)*	*.66 (.55)*

(Note: One liter equals 0.264 gallons. Above conversions to g.p.m. are by the Editor.)

* It is believed that this refers to the rate at which required accuracy is reached.—Ed.

corrosion of larger parts, such as the measuring chamber of disc meters, etc. In contrast to this there are many favorable experiences with brass. It seems to be impossible in any given case to predict whether there will or will not be corrosion. Chemical analysis seems unable to give a full explanation. Very favorable results have been obtained by coating with a hot black enamel (moffellak) all

the brass parts which require it. This enamel which does not harden, but retains some plasticity, and is very smooth, also reduces the lime deposits to a great extent.

As is well known, it is to the celebrated Friedrich Lux that the credit belongs of being the first to recognize to its full extent the value of ebonite as used in water meters. On account of his using ebonite of incorrect composition and also perhaps on account of minor faults of construction, the large-scale test with "the old Lux," now 40 years ago, was not successful.

The present German makers use ebonite wherever it can be used. The various parts are compressed, when possible, so that extremely smooth surfaces are obtained upon which hardly any deposits can form. It is naturally of great importance that the bored inlet and outlet channels of the runner compartment should be as smooth as possible and that they should have sharp edges.

It is easily understood that the requirements which the ebonite must satisfy are not alike for all the different parts. The ebonite for the usual pressure pieces (the runner compartment, runner itself, mechanism compartment, measuring chamber) has to satisfy different requirements from the ebonite for the mechanism (disc wheels, bearings). As I understand it, the important points in this connection are, among others, the free sulfur content, the amount of filler, the rigidity, the resistance to deformation at higher temperatures, etc.

Although in general very favorable results have been obtained by the use of nickel in water meters, there are also exceptional instances known of severe corrosion of nickel, in which it usually exhibited a laminated structure, reminiscent of the structure of old wrought(?) iron (welijzer). I do not know whether in these cases the composition of the nickel was the cause of the corrosion.

With the combination of nickel with ebonite extremely favorable results have been obtained.

SUBMERGED OR NON-SUBMERGED MECHANISM

The fight which in the past was carried on between "wet" and "dry" in the water meter field has died down in recent years. The

(Editor's Note:—In the meters having submerged mechanism all of the working parts including the register and the dial are within the pressure compartment of the meter. The meter dial is read through a thick glass which withstands the pressure, Figs. 8 and 9.)

opinion now generally accepted is that only in those cases where some special objection to a "wet" meter exists is a "dry" meter preferable. Practice teaches that more and more "wet" meters are being made.

PERIODICAL INSPECTION

It is well known that the sensitivity of water meters falls off with time, so that there is a risk that water passing through at a low rate of flow will fail altogether or in part to be registered by the meter. Corrosion, lime deposits, or the lodgment of foreign bodies in the meter's interior may bring about complete or partial stoppage of registration. On the other hand, sludge deposits in the inlet channels to the runner compartment may, for example, lead to an excessive over-registration.

For all these reasons, it is necessary that water meters be periodically cleaned, repaired, and tested. I take it that this opinion will meet with no opposition from water supply technicians in Holland.

It is possible, however, that the proper period between inspections is not alike everywhere. In this connection the composition of the water must be considered. It may be of great significance, as being for example aggressive, non-aggressive, or lime-depositing. The construction of the meter and the materials of which it is made are also of importance, with reference especially to wear and to corrosion. Experience here teaches that, in general, meters of older types need far more attention than the modern products.

It is also easy to understand that water works which have carried out an extensive metering program will react more sharply to erroneous meter registration than those where the meters have only exerted partial influence on the water revenues. It is also obvious in this connection that more attention should be given to large meters which, in many cases, pass especially large quantities of water, as compared with the smaller meters.

In German publications on this subject it is sometimes recommended that periodical inspection should take place every two years. It seems to me that for meters less than 15 years old this period is too short. In the Dune Supply of The Hague, it used to be the rule to inspect the meters every three years. This period has in recent years been lengthened to $3\frac{1}{2}$ years for 5-cubic-meter meters and smaller. For the 7-cubic-meter meters and larger, the three year period remains in force.

To accomplish this it is our custom to make out a list every half-

year of the meters due for periodical removal or inspection, so that for an average run of 3½ years, actual runs lie between 3 and 4 years. The small meters due for inspection are listed by streets on cards which are handed out to the workmen and on which they enter the size, number and make of the new meters as installed. The large meters are listed on separate sheets including the most important particulars regarding the premises and the water consumption. They also give the average and the highest monthly consumption during the elapsed period. Thus by employing a suitably skilled man at each change of meters a simple means is provided of exercising proper control in this extremely important department.

SHOP EQUIPMENT AND PERSONNEL

If circumstances permit, I consider it advisable that those works which have many meters should carry out the periodical examination themselves.

As to choice of personnel, it is clear that an instrument maker can perform all the necessary work without much difficulty. It has further been shown that watchmakers are particularly skillful at repairing meters.

The foremanship should be entrusted to a man with practical and theoretical experience in instrument making or tool making. In addition to the ordinary skill in instrument making, it is desirable to have special skill in fitting, etc., for different types of meters, of which there are a great number. It is also necessary to have available one or more small high-velocity instrument-makers' lathes (500 to 1000 r.p.m.) with so-called American chucks with which the object can be fastened or loosed while the lathe is running.

For the testing department a separate room is advisable, as also for the acid and alkali treatment used in the cleaning of the meters.

In my opinion, the testing equipments offered on the market by several of the German water-meter makers are all satisfactory.

For modern small meters, in which one revolution on the first dial corresponds to a flow of 10 liters (2.64 gals.), it is desirable, in order to save time when testing at low rates of flow, to use containers of not too large cross-section. Thus a quantity of 100 liters (26.4 gals.) in the container should preferably correspond to at least 400 mm. (15.7 inches) on the divided scale.

Fig. 12 gives a diagrammatic sketch of a testing outfit with differtial mercury manometer. The experimental manometer with water

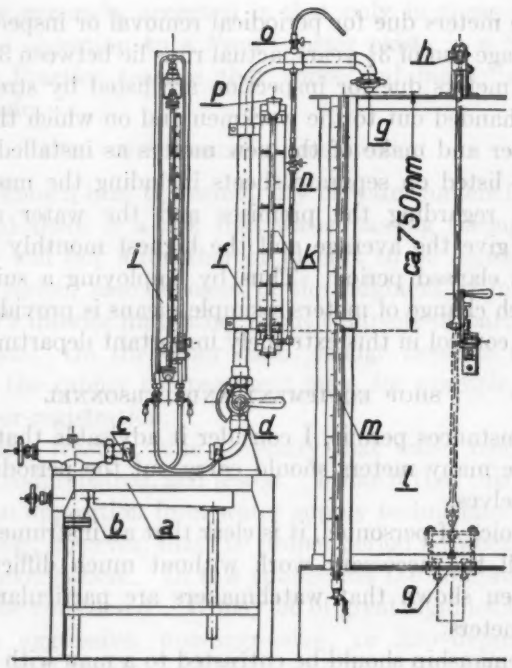


FIG. 12

FIG. 13

float has given better results at The Hague than an experimental mercury manometer.

Fig. 13 shows how the outlet nozzles are attached.

Fig. 14 shows the arrangement for a series test.

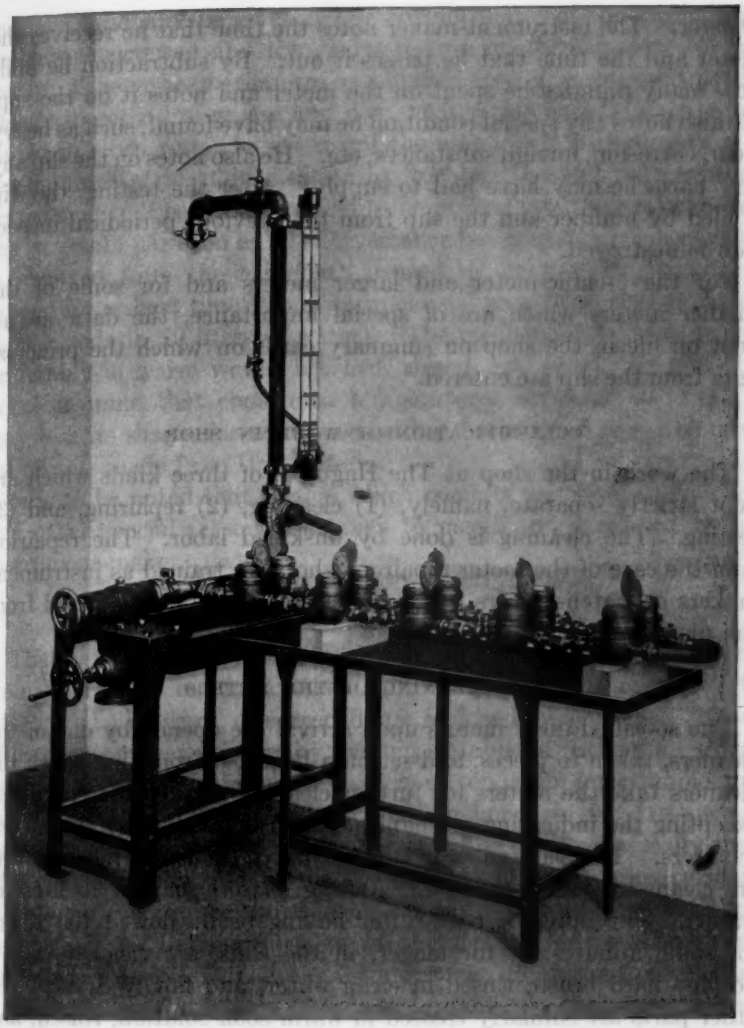


FIG. 14

SHOP SYSTEM

In the shop each meter receives a meter slip. On this slip are recorded the number and make of the meter, its reading, the date it comes in and the date it goes out. Columns are provided for test results before and after repairs including the percentage error at different rates of test flow and the rate at which the meter begins to

register. The instrument-maker notes the time that he receives the meter and the time that he passes it out. By subtraction he finds how many minutes he spent on the meter and notes it on the slip. He also notes any special condition he may have found, such as heavy wear, corrosion, foreign substances, etc. He also notes on the slip any new parts he may have had to supply. After the testing, the slip is filed by number and the slip from the previous periodical inspection is destroyed.

For the 5-cubic-meter and larger meters and for some of the smaller meters which are of special importance, the data are all kept on file in the shop on summary cards on which the principal data from the slip are entered.

CLASSIFICATION OF WORK IN SHOP

The work in the shop at The Hague is of three kinds which are kept strictly separate, namely, (1) cleaning, (2) repairing, and (3) testing. The cleaning is done by unskilled labor. The repairing is in the care of the meter repairers who were trained as instrument makers or watch-makers. The testers are preferably selected from the meter repairers.

THE CLEANING OF THE METERS

The so-called dirty meters upon arrival are opened by one of the cleaners, taken to pieces, and set on a bench. From this bench the cleaners take the meters for further cleaning of the different parts, excepting the indicating mechanism which is handled by the meter-repairers. The painted or enameled parts (housing, head, cover) are cleaned in warm soap suds (0.5 kg. of soft soap to 10 liters of water). The different parts after having been allowed to "soak" for some minutes, or for longer, in the suds, are cleaned with a not too hard brush, rinsed in clean water, and finally dried. The other parts are similarly treated in warm soda solution, rinsed, and dried. Very dirty parts are left over half an hour in boiling soda solution to loosen the dirt.

The water tight bearing of non-submerged type meters (still generally called the conical bushing) may be cleaned in coal oil.

The pointers or hands of so-called standard meters, which are made of Trolitul may only be cleaned in warm water of at most 25°C. (77°F.). In event of lime deposits being heavy, an acid treatment

may exceptionally be given. The bottom plates of the mechanism are first unscrewed and the shafts resting on them loosened separately. Then the mechanism is plunged into a warm soda bath, chiefly to get rid of grease and dirt. After this bath, the parts are rinsed in clean water to get rid of the alkali, and introduced for a few minutes at most into dilute hydrochloric acid (1 part concentrated acid to 2 parts water: acid to be poured into the water, never the reverse). As soon as all effervescence has ceased, the mechanism is removed from the acid bath, rinsed in clean water, and then dipped for a short time into a warm caustic soda bath (100 grams of caustic soda in 10 liters of water). The mechanism is then placed preferably in warm water, brushed, rinsed, and dried. It must be borne in mind that ebonite at temperatures above 40°C. (104°F.) may lose its shape, for which reason hot baths must never be used for objects made from this material.

It is to be noted that meters which come in as "stopped," or for any other special reason, are taken to pieces and examined by an instrument-maker.

REPAIR WORK

The meters cleaned and dried by the cleaners are set on a bench from which the repairers take them over into their care. Parts which are badly worn, or corroded, are replaced by new ones. Cases of less severe wear are met by making suitable adjustments. Shaft holes of the mechanism which have worn too large, for example, are punched down to be too tight and then bored to fit. In special cases, they are bushed. The free ends of the shafts, especially that of the transmission shaft of the dry meters and of the primary shaft of the wet meters are rounded on the lathe if necessary and then polished. The bearing surfaces of these shafts are also made as smooth as possible with the polishing steel. Shafts out of true are set straight on the lathe. The boss (around toe of runner) is also polished and the toe trued up. The shaft of the runner is also polished. It is sometimes necessary to re-center the toe in the runner compartment. It is a well-known phenomenon that rough surfaces are far more susceptible to corrosion than smooth. Hence it is desirable to polish as much as possible, especially parts in motion. Any deposits are cleaned out from the openings in the bearing plates with a wood splint. The bearing plates through which the

shafts run are reversed (either turning each plate upside down, or else the upper and lower plates are interchanged (oingekeerd)), or else they are given a slight angular displacement. Damaged spots in the enamel coating of brass parts are painted over with an air-drying black bituminous enamel.

OILING THE MECHANISM

To avoid lime deposits, and probably serving also as a protection against corrosion, the metal parts, especially the transmission and the mechanism are dipped in a bath of light paraffin oil and centrifuged to remove excess oil.

ASSEMBLING THE METERS

After all these repairs, the meters are assembled. A skilled meter-repairer can now form a good idea of the post-repair sensitivity of the meter by giving the runner a spin and observing the working of the mechanism. With the help, if necessary, of gages (mallen), but, as a rule, from experience, he knows exactly the level at which to set the toe and the runner, and also to adjust the amount of vertical play of the runner shaft. By finally blowing into the meter a very good idea of its sensitivity is obtained.

TESTING AND ADJUSTING THE METERS

The 7-cubic-meter and larger meters are always tested in their dirty condition within a few days after their removal, by flow capacity tests. Their sensitivity is also determined. In the case of the smaller meters these determinations are made as random tests (steekproeven). The repaired meters are tested by actual flow tests. The sensitivity is also determined, and one or two tests are made at flows of 2 to 5 per cent of the capacity. From time to time, series tests are carried out over the whole range of the curve of error. In order to save time, series testing is used as much as possible, especially for low rates of flow. It is important in this case that all the air be driven out of the meters before beginning the tests. For ordinary testing at greater rates of flow, the pressure in the distribution system is always made use of. There is no objection to this provided that pressure fluctuation is not excessive. With sharp increase of pressure, readings will be too high. For exact series

testing, it is advisable, however, to maintain the pressure constant for low rates of flow. This is to avoid the errors due to residual air bubbles which by contraction under pressure increases and later re-expanding may cause excess readings of many per cent.

In case any of the meters do not fall "within the limits" at the first test, they are adjusted by the tester, if they have an external regulator. If not, they are adjusted by their respective repairers. After the final test they are sealed and painted.

The quantity of water for each test must not be less than 100 liters (26.4 gallons). For rates of 1000 liters per hour (4.4 g.p.m.) and upward, larger quantities of 200 to 300 and up to 500 liters are preferable. Account must be taken of the relation between the volume indicated by the meter and the scale on the measuring tank.

Under favorable conditions quantities of 20 to 50 liters will suffice for testing.

For calculating the error proceed as follows: Let D be the quantity of water which has actually passed through the meter and A the quantity as indicated by the meter, then,

$$\text{the error, } F = \frac{(A - D) \times 100}{D}$$

For example, if $D = 110$ liters and $A = 100$ liters, then

$$F = \frac{-10 \times 100}{110} = -9.1 \text{ (per cent)}$$

and if $D = 100$ liters and $A = 110$ liters, then,

$$F = \frac{+10 \times 100}{100} = +10. \text{ (per cent)}$$

If, on the other hand, we know the error, F, and the quantity A, as indicated on the meter, then the true quantity, D, which passed the meter is given by the formula:

$$D = \frac{A \times 100}{100 + F}$$

For example, if $A = 100$ liters and $F = +10$, then

$$D = \frac{100 \times 100}{100 + 10} = 90.9 \text{ liters}$$

and if $A = 100$ liters and $F = -10$, then

$$D = \frac{100 \times 100}{100 - 10} = 111.1 \text{ liters}$$

EXPENDITURE OF TIME

Experience at The Hague shows that a team of two men can exchange from 60 to 75 meters per day, which works out to about 15 minutes per man per meter.

The time spent in cleaning a meter is about 15 minutes, and in repairing, about 50 minutes. For testing, sealing, and painting the outside 5 or 10 minutes can be taken as the average.

Thus the total expenditure of time for all these operations can be set at about 90 minutes at The Hague.

REGISTRATION OF METERS

As is well known, volume-type meters have, naturally, an almost horizontal curve of error. Velocity (runner) type meters differ fundamentally from this. An important contribution on this subject has been given by G. Eggers in the Archives of Technical Measurements, June, 1936,—"Volume Measurements of Liquids by Means of Propellor Meters." (German.)

A runner-type meter without guide vanes gives a curve of error which is anything but horizontal. In fig. 15 various curves of error are shown graphically. Curve *a* represents the registration of a 5-cubic-meter meter from which the guide vanes both over and under the runner had been removed. When the quantity passing the meter is 5 cubic meters per hour (22 g.p.m.), the registration shows a plus error of over 75 per cent. When the guide vanes over the runner are put back in place, we get the error curve *b* which shows a plus error of 27 per cent at capacity flow. If run with only the lower guide vanes in place, we get curve *c*, with a maximum plus error of 16 per cent. By comparing *b* with *c* it is clear that the underneath guide vanes are more effective than the upper ones. It is also remarkable that *c* is nearly horizontal. When all the guide vanes, above and below, required by this meter are in place, the curve of error takes the form *d*. When the flow reaches 40 liters per hour (.18 g.p.m.), the throttling effect begins to be evident. Subsequently there appears the characteristic "hump" for runner-type meters which in this case changes into a depression at 150 liters per hour (.7 g.p.m.).

Further on the curve rises again somewhat. By increasing the throttling action a curve *e* is obtained which slopes more sharply downwards. The appearance of the "hump" is not to be explained by the throttling action alone. It is thought that the registration

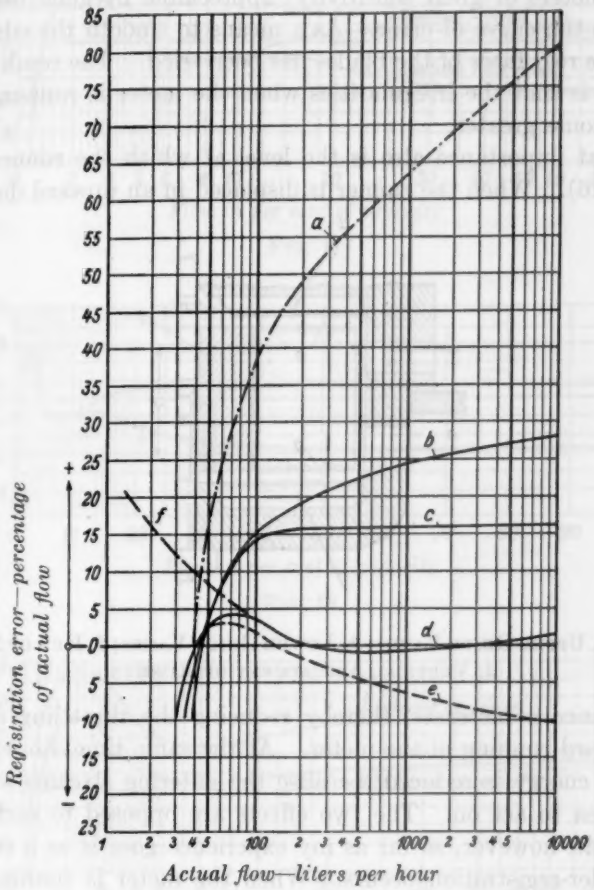


FIG. 15

by the meter must be regarded as a function of the Reynolds number which is interfered with by the mechanical friction only in the case of the low flows. Were this friction eliminated, the curve *d* would then continue to the left as shown by *f* and give still higher plus values in this region.

Besides the proper adjustment of the guide vanes, the correct play of the runner in its compartment (diameter of the blades) is of the greatest importance, as also is the number of blades. Moreover the number, the bore, and the condition of the inlet and outlet channels have an effect on the registration.

With meters of great sensitivity, appreciable irregularities often appear in the curve of error. As a means to smooth the curve, tapering the rear faces of the blades has been tried. The result of this however, is that the irregularities when the meter is running in reverse become greater.

Of great importance also is the level at which the runner is set (see fig. 16). When the runner is displaced in an upward direction,

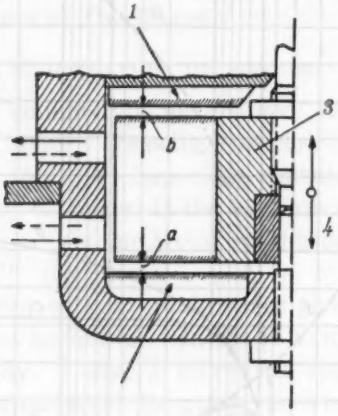


FIG. 16. *1*, UPPER GUIDE VANES; *2*, LOWER GUIDE VANES; *3*, HUB OF RUNNER; *4*, VERTICAL ADJUSTMENT OF RUNNER

the distance *a* increases, thereby reducing the throttling effect in the forward running of the meter. At the same time, however, the input of energy is reduced, because the entering streams have less blade area to act on. The two effects are opposed to each other. The result, however, so far as my experience goes is as a rule such that under-registration occurs. When the meter is running in reverse, with an upward displacement of the runner the same things happen the other way round. Thus over-registration is to be expected.

In fig. 17 is shown for a "standard multi-jet meter" the effect of too much vertical play, *t* of the runner shaft. (The upper curve shows the effect of the correct amount of play. The lower curve shows the effect of too great play.—Ed.)

In fig. 18 the same is repeated, but with a linear scale instead of a logarithmic one. In fig. 19 is shown the effect on the same type of

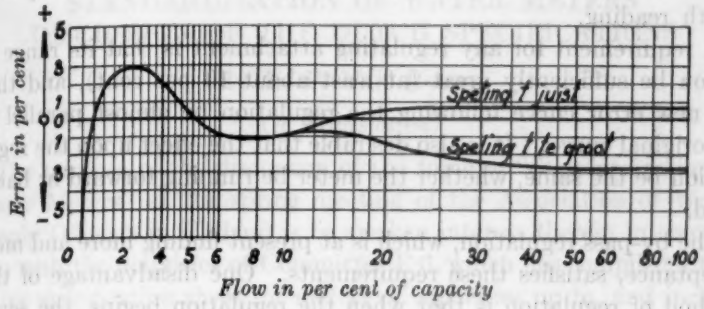


FIG. 17

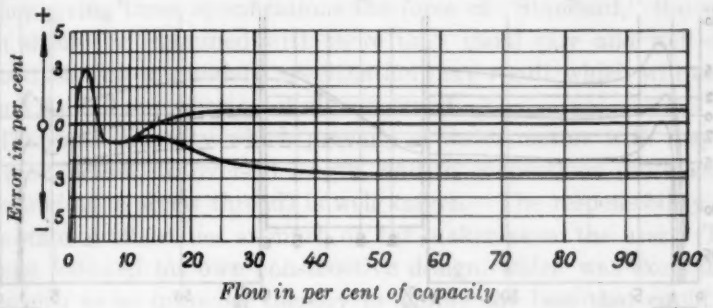


FIG. 18

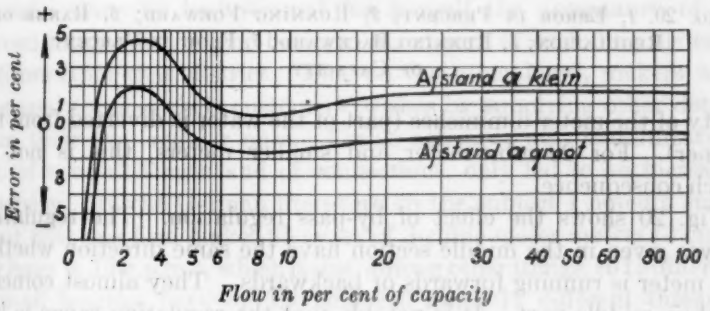


FIG. 19

meter of incorrect clearance below the runner (*a* in fig. 16). (The upper curve shows the effect of too small clearance. The lower curve shows the effect of too large clearance.—Ed.)

REGULATION OF RUNNER TYPE METERS

A. Denkert in Das Gas—Und Wasserfach No. 41, of Oct. 10, 1934, gives a discussion of runner-type meter regulation which is very well worth reading.

A requirement for any regulating attachment is that its range of action be sufficiently great (at least about 10 per cent), and that the new error curve following the regulation be almost parallel to the original curve. It is also desirable that the effect upon the registration be the same, whether the meter be running forward or backward.

The by-pass regulation, which is at present finding more and more acceptance, satisfies these requirements. One disadvantage of this method of regulation is that when the regulation begins, the sensi-

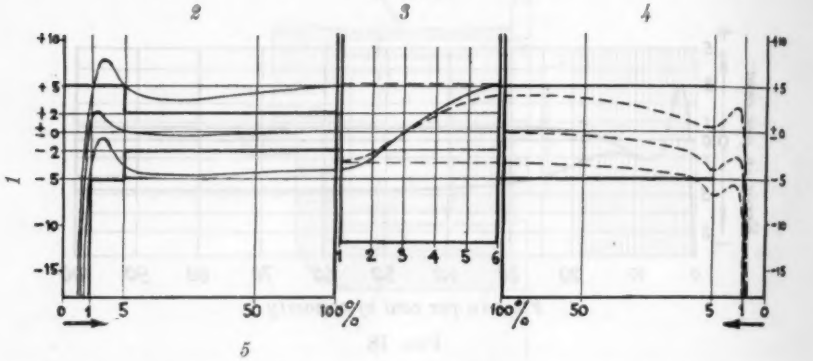


FIG. 20. *1*, ERROR IN PERCENT; *2*, RUNNING FORWARD; *3*, RANGE OF REGULATION; *4*, RUNNING BACKWARD; *5*, FLOW IN PERCENT OF CAPACITY

tivity of the meter diminishes (part of the water is diverted from the runner). For 20-cubic-meter and smaller meters, this is not of much consequence.

Fig. 20 shows the effect of by-pass regulation. The regulation curves given in the middle section have the same direction whether the meter is running forwards or backwards. They almost coincide at their middle part. It is notable that the regulation range is less for backward runs than forward.

The firm of Siemens and Halske of Berlin have kindly supplied the material for many of the above illustrations. This kind cooperation is gratefully acknowledged.

(A number of the cuts for the illustrations were loaned to the American Water Works Association.—Ed.)

STANDARDIZATION OF WATER METERS
DISCUSSION OF THE DUTCH SPECIFICATIONS

By R. P. Van Royen

(A Translation)

The purpose of the discussion of the topic of "Standardization of Water Meters" at the spring meeting of the Association of Water Supply Officials in Holland is to awaken interest therein in connection with the activities of Committee P 6, which has compiled a tentative specification sheet for meters of capacities up to, and including, 20 cubic meters per hour (88 g.p.m.). It is desirable that, before giving these specifications the force of "Standard," the subject should be examined with more than usual care and well discussed, so that a standard specification may result which will command the full approbation of all concerned.

The great diversity which prevails in water meters with respect to construction, to over-all length, and to connections (both as to bore and as to screw thread) is well known. The responsibility for this state of affairs lies as much on the maker as on the user. The former followed his own constructive design, which was excusable, inasmuch as he intended thereby to supply the best that could be had, but also his own particular details, as for example the screw thread. Once he had secured for himself the acceptance of his thread in any district, he bettered his chance of excluding his competitors from that district. But, on the other hand, makers were prepared to meet their customers' wishes by supplying other details than their own regular ones. Feeble attempts at standardization, e.g. of over-all length and of connections, only led to an increased diversity. In the German literature on the subject I noted a statement that one firm makes 65 types of 3-cubic-meter meters (3 cu.m. per hour = 13 g.p.m.), which is due, among other things, to 15 different over-all lengths, between 130 and 220 mm.; 11 different threaded

A paper presented at the general meeting of the Association of Water Supply Officials in Holland, May 21, 1937, by R. P. Van Royen, Director of the Amsterdam District Water Supply. Printed here by permission of the Secretary. Translation from "Water" (Neth.) by Frank Hannan.

ends, of diameters from 23 to 38 mm.; besides flange joints of 10 different patterns. The number of boxes for meters up to and including 40 mm. was no less than 185.

Does this offer any encouragement for standardization?

The answer to this question does not seem easy. For if the answer be given in the affirmative, then full cooperation on the part of the users is necessary to conform thereto. And when this has been done, there will still remain much diversity. There will always be the choice between runner type and volume-type meters; between single jet and multi-jet meters; between fixed dials with revolving indicators, and digits exhibited on the circumferences of revolving discs; between submerged and non-submerged mechanisms. The over-all length and connections can, however, be uniform for all the different types of construction, and standards can be laid down for various parts and for the testing of the meter and the exactness of its indications. It is obvious that the fixed parts and the nature of the material must here be left out of account. While the makers seem certainly to have reached finality, yet it must be held more desirable not to fetter the spirit of invention by stereotyping the patterns any further.

The evolution in this field within recent years has indeed clearly indicated that new possibilities must still be reckoned with, although it may be in many respects a matter of indifference to the user whether finality in the way of improvement has actually been attained. Nevertheless we must still cherish the hope, that new surprises may yet be in store with respect to the efficiency and durability of these instruments.

It is now some years since Standardization of Water Meters was decided upon in Germany, and in 1935 two specification sheets, Din 3260 and 3261 appeared, covering domestic meters for cold water. These sheets deal with runner-type and volume-type meters of capacities 3, 5, 7, 10, and 20 cubic meters per hour (13, 22, 31, 44 and 88 g.p.m. respectively) under a pressure drop of 10 meters (33 feet). Couplings are specially dealt with in Din 3261.

Standardization work on water meters was begun by Committee P 6 (i.e. the Dutch Cie.) in 1933. There has been extensive consultation with the German committee. On certain points both bodies have found themselves in agreement, while on others their views still diverge.

P 6 work has reached a stage such that a tentative specification sheet will soon be published.

The following remarks refer to certain points in this standardization, special attention being given to points of difference from the Din (German) specifications. The sizes of meters continue to be expressed as their capacities in cubic meters per hour under a 10-meter (33-foot) pressure drop.

With respect to over-all length, the D.N.A. (German Cie.) has introduced a change. There were three specified lengths, namely, 220 mm. (8.66 inches) for the two smallest sizes, 260 mm. (10.23 inches) for the next two sizes, and 300 mm. (11.81 inches) for the largest size. The over-all length of 220 mm. for the 3- and 5-cubic meter sizes has been reduced to 190 mm. (7.48 inches). The pipe connections for the two smaller sizes are 20 mm. (0.79 inch), for the next two sizes, 25 mm. (0.98 inch), and for the largest size, 40 mm. (1.57 inch). The corresponding union thread sizes are 1″, 1¼″, and 2″. D.N.A. has therefore enlarged the pipe connection for the 3-cubic-meter size and reduced that for the 10-cubic-meter size.

P 6 considers that it cannot fully accept the proposed regulations governing over-all length and pipe connections.

Thus, for the 3-cubic-meter meter, the existing short over-all length of 165 mm. (6.49 inches) is maintained. The reason is, that this size of meter constitutes in many water supplies a very large percentage of the meters in use; and that, moreover, the convenience of being able to exchange a 3-cubic-meter meter for a 5-cubic-meter one, or vice versa, is not a matter of such great importance, as to justify the adoption of the greater over-all length. The limited space available in the existing meter pits has also been taken into consideration. For the larger sizes, the over-all lengths are in agreement with D.N.A. For the change from a larger to a smaller over-all length, that is to a smaller meter, Din 3261 specifies certain standard fittings. P 6 has not adopted these.

P 6 has not adopted the combinations of pipe sizes; it therefore retains the existing standard sizes 13, 19, 25, 32, and 38 mm. (0.51, 0.75, 0.98, 1.26, and 1.50 inches) corresponding to the nipple sizes specified in N457. D.N.A. also specified the sizes 19, 25, and 38 mm.; but omits, as already pointed out, the sizes 13 and 32 mm.

The nipples specified in N457 are a trifle shorter than those of Din 3261, which is unimportant.

The union-couplings according to Din 3261 are almost completely in accordance with those of N459. It may be remarked that these originated from the standard wrench sizes according to N84, which resulted in great difficulty of manufacture. In order to overcome

this trouble, a new tentative specification has been issued in which the wrench measurements have been fixed upon considerations of adequate strength only, thus being independent of N84—standard wrench measurements. These union-couplings are perfectly satisfactory for pipe work; they differ accordingly from those of N459 and Din 3261.

Choice of type,—that is to say volume-type or runner-type, single jet or multi-jet, submerged or non-submerged,—is left entirely to the user; as also is the method of making the chamber water tight. Some parts are definitely specified, e.g., a regulating attachment controllable from outside, which must, like the cover, be able to be sealed; a cover with overlapping edge to protect the glass plate from entry of water; the mechanism, which for 3-cubic-meter meters must be able to register up to 1,000 cubic meters (264,000 gallons) and for the other sizes, up to 10,000 cubic meters (2,640,000 gallons); must be fitted with hands revolving only to the right; ability to run backwards; and some other miscellaneous regulations.

Further, a test pressure of 16 kg. per sq. cm. (228 lbs. per sq. in.) is prescribed to correspond with the nominal working pressure of 10 kg. per sq. cm. (142 lbs. per sq. in.) which is in force for cast iron pipe. This test pressure has been set by D.N.A. at 20 kg. per sq. cm. (285 lbs. per sq. in.).

Uniformity has at last been attained between German and Dutch specifications with respect to the sensitivity requirements and as to accuracy of registration both when running forwards and when running backwards. The D.N.A. were inclined to raise the limits, both for start of registration and for accuracy, believing that the limits given in some of the lists are either not reached or reached only with difficulty in practice. The values now given may be regarded as limiting values, which at least must be met. In agreement with Din 3260, a limiting value has been adopted with respect to the positive peak in runner type meters, namely by accentuating the requirement that the algebraic difference between this value and the percentage registration error at half-capacity flow shall not exceed 5.

Agreement has further been reached with respect to permissible error of registration when running backward which has been set at ± 5 per cent for runner-type meters and ± 2 per cent for disc meters.

DISCUSSION OF METER PRACTICE IN HOLLAND

(An abstract)

Editor's Note: The two preceding papers by R. P. Van Royen and A. J. Gurck were presented at the general meeting of the Association of Water Supply Officials in Holland, on May 21, 1937. A report of the discussion of them appeared in "Water" (Netherlands), issue of Jan. 14, 1938, and is here briefly abstracted. Abstract by Willem Rudolfs.

R. P. VAN ROYEN: Questioned whether the use of nickel and ebonite is necessary in corrosion prevention. Emphasized necessity for meter construction suitable for measuring reverse flow. Points out that rotary counting mechanisms (straight reading dials?—Ed.) may be used as well as those with clock hands. The usual register indicates to 10,000 cu. meters (2,640,000 gal.). The wet runners (meters with submerged mechanism) have 3 hands, for 10 x 1 liters, 10 x 10 liters, 10 x 100 liters, and either 4 or 3 hands for 10 x 1 cu. meters, 10 x 10 cu. meters, 10 x 100 cu. meters and 10 x 1000 cu. meters. Dry runners have one central hand for 100 liters and one small hand for 10 liters. The hands run to the right. Accuracy and sensitiveness require not only good general design but also good detailed construction. The volume meter gives better results than the wing wheel meter. A comparison of the characteristics of the three types of meter is given in fig. 2A.

Fig. 2B is a diagram of the proposed accuracy specification for a 3-cubic meter per hour (13-g.p.m.) meter. Previous specifications made no allowance for the high point in the curve. The proposed specification allows up to $\pm 5\%$ for flows up to 5% of capacity. This also increases the leeway at the limit of accuracy but this is not considered important because the curve is rising sharply at this point.

The regulation of the modern wing wheel meter is by means of a screw which regulates the opening of a by-pass. The volume passing the by-pass is an approximately constant percentage of the total

volume passing the meter, and this percentage is subtracted from the volume available to turn the meter. This may be as much as

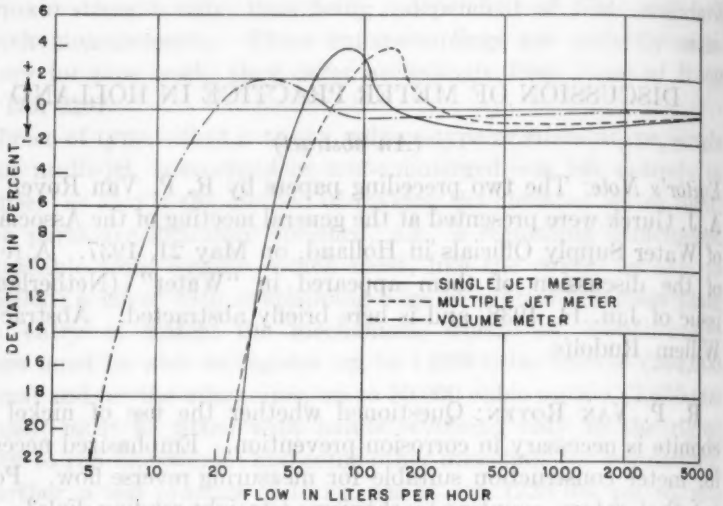


FIGURE 2A

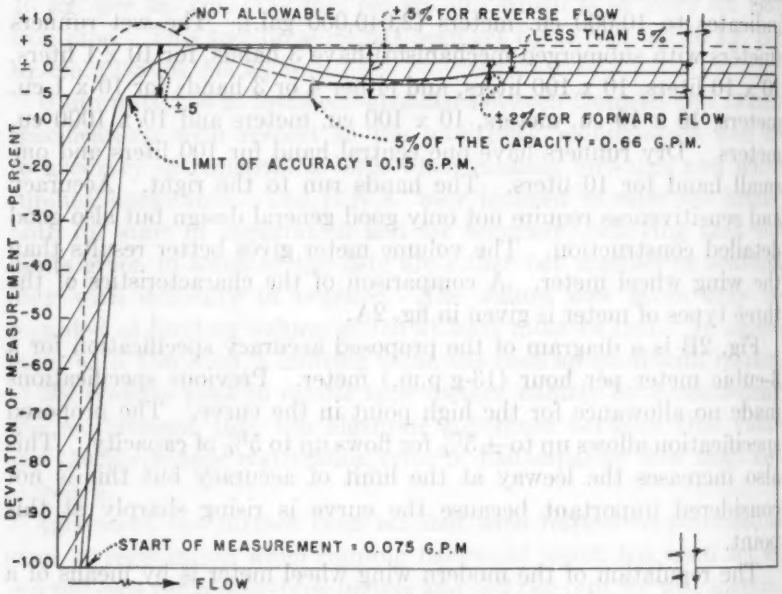


FIGURE 2B

10% of the total, and the specifications for sensitivity and accuracy must be met in spite of this.

F. G. VAN RANDWIJCK: Called attention to the relatively few small meters (2 cubic meter per hour = 8.8 g.p.m. capacity) in use in some cities, while in others there are many such meters. This depends on the difference in water consumption in the cities, which in The Hague is 300 liters (79 gal.) per capita and in Haarlem but 130 liters (34 gal.). The Hague has a meter charge, while the cost per cubic meter rate is determined by the rental value of the house. The smaller the wing wheel and the greater the number of its rotations the greater will be the sensitivity. The rotations for 1 cu. meter of water in a 1.2-cu. meter meter (5.3 g.p.m.) is about 50,000; for a 2-cu. meter meter (8.8 g.p.m.) about 40,000; for a 3-cu. meter meter (13 g.p.m.) 25,000, etc. This results in much more rapid wear of the small meters in the pins and sockets. Meters are periodically examined (every 3 to 4 years) and cleaned; no repair is necessary. The meters are lacquered inside and painted outside. Before 1923 dry runners were used nearly exclusively in The Hague, since then mostly wet running wing wheel meters have been used.

P. JONGEPIER: All water should be metered whether paid for or not. In many places water for city purposes is not paid for. At Bloemendaal the water losses have been reduced from 20 per cent in 1927 to 9.2 per cent in 1936 by careful and continuous control. Small meters are better, because of their low starting rate and accurate measurement of small quantities. Experiments with different types of meters with small flows showed volume meters to be far superior in the registration of such flows with wet runners the next. The new dry runner begins to operate accurately with a rate of 100 liters per hour (.46 g.p.m.) and the error with certain small usages may be 100%. Wet runners are preferred.

J. H. SCHNEIDER: Experience has shown that modern multiple stream meters give irregular registration with constant use. They must be carefully checked. Some of the wet runners freeze in cold weather.

G. SCHROEVERS: Combination (compound) meters, wet runner and volume meter, are very accurate. An example given registered 61 out of 69 liters passed in 20 hours, a rate of 3.5 liters per hour (0.015 g.p.m.).

A. J. GURCK: The characteristics of a 1.2-cu. meter meter are more favorable for measurement than those of a 3-cu. meter meter of the same type. A flat error curve is desirable. Pressure loss is greater with the smaller meter,—the loss is 7 meters with 1,000 liters per hour through a 1.2-cu. meter meter, and only 1 meter with the larger meter. In most cities in Holland the pressure is from 20 to 25 meters above the street level and a loss of 7 meters is undesirable. Meter types should be kept to a minimum. Until 20 years ago many American meters were in use in The Hague; the error curve of these meters was undesirable in comparison with the wing wheel meters; up-keep was high. Smaller German meters of the same type were poor; corrosion excessive. Caution should be used in the use of nickel in water meters; corrosion is rapid; structure is not uniform; analyses do not reveal the reasons for the difficulties. Nickel gains a protective coating with acids or alkalies. Discussion and figures are given as to the determination and extent of water losses. Freezing breaks the glass in both wet and dry runners.

WATER PROBLEMS ENCOUNTERED IN THE MINING OF SULPHUR

By Homer S. Burns and Homer A. Smith

THE SULPHUR MINING INDUSTRY

Sulphur mining, according to modern methods, is an industry of interest to water supply engineers because of the large amounts of water consumed and the problems encountered in its purification and subsequent handling. Prior to the year 1903, practically all elemental sulphur was produced in Sicily, by conventional mining methods. The ore, consisting of limestone and sulphur, was mined underground and brought to the surface, where the sulphur was separated from the rock by the action of heat, usually generated by burning a portion of the sulphur. This crude method of mining is still used today in Sicily because of the peculiar formations in which the sulphur exists and the lack of fuel and water.

In 1869, during drilling for oil at Sulphur, Louisiana, sulphur was discovered in the limestone cap rock of a salt dome. Several companies became interested in this deposit and attempted to mine it by the methods used in Sicily. Attempts to sink a shaft to the ore body failed as a result of quicksand formations and the large volumes of poisonous gas encountered.

Herman Frasch conceived the idea of drilling wells similar to those used in the production of oil, melting the sulphur in the formation by forcing superheated water into the wells, and subsequently pumping the molten sulphur to the surface. Production of sulphur in this manner was begun in 1902. Modern practice in the construction of these wells is shown in figure 1. Water at 300° F. or higher is forced into the formation through perforations in the outer pipe; the molten sulphur enters the bottom of the well and rises through the inner pipe around an air line terminating about 300 feet from the bottom. From this point the sulphur is brought to the surface by means of air

A paper to be presented before the meeting of the Joint Boiler Feed Water Research Committee at New Orleans, April 26, 1938 by Homer S. Burns and Homer A. Smith of the Freeport Sulphur Co., New Orleans, La.

lift. Water is subsequently withdrawn from the formation by means of bleedwater wells to permit continuous circulation of hot water through the porous limestone rock for the purpose of melting sulphur.

The successful development of the Frasch process has made possible the present sulphur industry in the United States. The mine at Sulphur, Louisiana produced over ten million tons of sulphur. The Bryanmound dome of the Freeport Sulphur Company was the

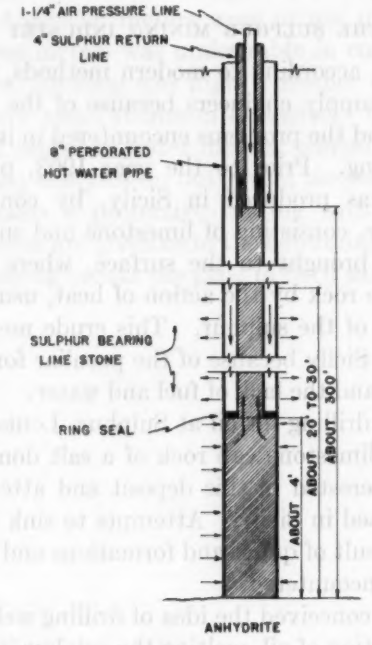


FIG. 1. SCHEMATIC DRAWING SHOWING CONSTRUCTION OF LOWER PART OF SULPHUR WELL

first deposit to produce sulphur following the original Frasch invention at Sulphur, Louisiana. Many other mines have been developed since 1902, including Big Hill, a property of the Texas Gulf Sulphur Company which started operations in 1919; Lake Peigneur of the Jefferson Lake Oil Company; and Palangana Dome of the Duval Texas Sulphur Company. Of the seven mines which are producing at the present time, two are operated by the Freeport Sulphur Company: one at Hoskins Mound, Texas, and the other at Grande Ecaille, Louisiana.

Sulphur wells are drilled (by methods commonly used in the oil industry) through unconsolidated sediments until the cap rock of the salt dome is reached. At this point a casing is set to protect against the caving of the upper sediments, and drilling is continued through barren limestone formation into sulphur bearing limestone (which is encountered at 600 to 2,000 feet in the Gulf Coast deposits) and is discontinued when anhydrite is reached. Underlying the anhydrite are impenetratable depths of salt. This formation is typical of all Gulf Coast salt domes. However, commercial sulphur has been encountered in the limestone of only a few of these structures.

DEVELOPMENT OF THE WATER SUPPLY FOR THE LOUISIANA MINE AND PREVENTION OF PIPELINE CORROSION

The most important raw materials required by the sulphur mining industry are fuel and large quantities of fresh water. The mine of the Freeport Sulphur Company at Grande Ecaille, 50 miles south of New Orleans, uses the Mississippi River as a source of water supply. The quality of the river water fluctuates according to the tides and the run-off of fresh water. Typical of the seasonal change in concentration during the dry summer and fall is an increase of hardness from 110 parts per million to 800 parts per million, and of sodium chloride from 34 parts per million to 3,400 parts per million. Since the salt content of the river during dry weather increases with depth because of the inflow of the heavier tide water on the bottom, the suction is taken as near the surface as possible. A pumping station with a capacity of 18 m.g.d. and a 70 million gallon settling reservoir are located at the river. The reservoir provides for presedimentation as well as storage of fresh water during periods of excessive salinity. Water is pumped from the reservoir to the mine, a distance of 9 miles, through lines of welded steel pipe supported on piling bents. The first mile and a half is constructed of two parallel 12-inch lines while the remainder is a single 14-inch line.

During early operation of the plant the line's original carrying capacity of 4,090,000 gallons per day declined to 3,170,000 gallons per day in four months because of the development of rust tubercles, which were accompanied by severe pitting. Mining operations were being restricted by the limited water supply and to restore capacity the line was cleaned periodically with a "go-devil" scraper. The line was cleaned in 2½-mile sections while operation was kept continuous by drawing on water stored at the plant. This expedient

did not remove the threat of rapid destruction of the pipe and means of preventing the corrosion were immediately investigated.

Information secured from several water works plants indicated that a protective coating could be deposited in the line by closely controlled treatment. Sodium silicate treatment was carried on for three weeks to deposit a protective film of calcium silicate but effected no reduction in the quantity of oxygen absorbed in the line and failed to lay down the desired coating. Moreover, the development of silica scales in the boilers indicated that the use of this treatment would have been hazardous. Attempts were then made to obtain calcium carbonate coatings by lime treatment of the water in the reservoir. The composition of the raw water was not adapted to this treatment and varied widely; difficulty in obtaining uniform thickness of deposit then led to the abandonment of this method of correction.

The dissolved oxygen content of the water during its passage from the reservoir to the plant, was reduced from 7.6 parts per million to 2.0 parts per million, and attention was directed toward prevention of corrosion by removing the dissolved oxygen from the water entering the line. Chemical deaeration with sodium sulphite, although expensive, required a minimum of equipment and was adopted as a temporary expedient for a period of 6 months. It proved to be very successful; there was only a minor loss in capacity after the sulphite treatment was started and inspections of the pipe indicated that the growth of rust tubercles had been practically eliminated.

During the period of treatment with sodium sulphite, experiments were conducted in the removal of oxygen with a vacuum deaerator, following the general principles of a plant that had been operated successfully at Coolgardie, Australia for a number of years. A pilot plant of considerably simplified construction was built and was found to be capable of reducing the dissolved oxygen from 7.6 parts per million to 0.5 part per million when a vacuum of 28.5 inches of mercury was maintained. Comparison of the test pipe carrying deaerated water with a control pipe carrying ordinary water indicated practically complete elimination of corrosion. The success of these tests led to the construction of a full-scale vacuum deaerator, consisting of a vertical steel tank 8 feet 6 inches in diameter and 19 feet high, packed with wooden slat bundles made of ordinary building lath. An 18-inch x 7-inch reciprocating dry pump connected to the top of the tank maintains sufficient vacuum to lift water from the

reservoir into the top of the deaerator, where it is distributed by perforated pans into small streams which fall through the packing, exposing a large surface and permitting rapid release of dissolved gases. The deaerated water is drawn from the bottom of the tank by pumps which discharge into the nine-mile pipe line. Supplementary sodium sulphite treatment is used to absorb the final traces of dissolved oxygen.

Design of the deaerator and pumps was based on final gas concentrations proportional to the partial pressures within the chamber, as required by Henry's law, and since gas solubilities increase as the temperature is lowered a seasonal fluctuation in efficiency was predicted. The attainment of theoretical performance can be accomplished by means of a large surface exposure and time sufficient to reach equilibrium, both of which are dependent on the length of fall through the tank. In practice this deaerator, which provides a fall of 12 feet, reduces dissolved oxygen from 8 parts per million to 0.25 parts per million when 1,800 g.p.m. of water at 80°F. are deaerated under a vacuum of 28.3 inches of mercury. If the length of fall is reduced to 4 feet the final dissolved oxygen concentration increases to 1.2 parts per million. At 44°F. the residual oxygen is about four times as high as at 80°F. Performance is not sensitive to total flow within the rated capacity of the apparatus.

When the deaerator was put into service it was indicated that corrosion was immediately inhibited, and during three years of operation results have been very satisfactory. Slight losses in capacity occur during the winter months, possibly due to less complete deaeration and slower reaction of the sodium sulphite at the lower temperature. It has been necessary to clean the line only once since the vacuum deaerator has been in operation and practically no tuberculation was found at that time.

SOFTENING OF BOILER FEEDWATER; SOLVING PRESSURE FILTER PROBLEMS AND OTHER DIFFICULTIES

Approximately one-fourth of the water used in sulphur mining is converted to steam, and as the boilers are operated on 100 per cent make-up it is necessary to control the feedwater treatment closely to avoid scale and corrosion. Feedwater for the 200-pound boilers at the Grande Ecaille plant is prepared in a hot-process lime-soda softener using copperas as a coagulant. Sufficient exhaust steam from plant equipment is added to maintain a softening temperature of

220°F. The average hardness of the softened and filtered water is 10 parts per million, which is finally treated by feeding di-sodium phosphate directly to the boilers. Salt cake is used as needed to maintain sulphate-alkalinity ratios for prevention of caustic embrittlement.

Difficulties have been experienced in the operation of the horizontal calcite filters following the hot process softening tank. Growth and compacting of the fine calcite grains, caking of the bed, and blow-holes have occurred at various times. Air agitation prior to backwashing caused the hot water to flash into steam, producing violent agitation and loss of fine calcite. Omission of the air agitation resulted in caking, mud-balls and incomplete cleaning. One solution of this difficulty was found in the use of sufficient live steam to bring the temperature to the boiling point, which gives uniform agitation throughout the entire backwashing period. In one filter an upper section of calcite has been replaced with anthracite as an experiment. Better cleaning of the bed may result from the higher ratio of expansion during backwashing, and the growth of the fine calcite grains will also be avoided.

In softening the water supply for the Hoskins Mound mine, in Texas, advantage is taken of the high concentration of sodium bicarbonate in the water drawn from 600-foot wells. Surface water, which is only satisfactory for use after abundant rains, is stored in a 300 million gallon reservoir. A mixture of the surface and well waters is softened in a cold process system similar to that used in municipal practice, providing mixing in a baffled flume and ample detention in settling reservoirs. Because of the high sodium content of the well water, it is only necessary to use lime and a coagulant to produce a filtered water with a hardness of about three grains per gallon.

At this plant a solution of sulphur dioxide is being used experimentally to treat the boiler feedwater. The sulphurous acid reacts with the alkaline water to form sulphites, which absorb residual dissolved oxygen and are converted to sulphates. The treatment therefore not only provides chemical deaeration to prevent corrosion, but aids in maintaining the sulphate-alkalinity ratio for the prevention of caustic embrittlement.

PREPARATION AND HANDLING OF THE MINE WATER SUPPLY

In carrying out the Frasch process of sulphur mining, large quantities of water at high temperatures must be distributed throughout the

sulphur well field and discharged through the wells into the sulphur-bearing limestone formation. One distribution system supplies treated water at 220°F., while another system provides water which has been heated by direct addition of steam to 387°F. at a pressure of 250 pounds. Properly tempered water for each individual well is obtained by mixing the two supplies. The deposition of scale in the hot water distribution system can be prevented by removing most of the carbonate hardness, since calcium sulphate remains in solution at the existing concentrations in these water supplies. Mine water is therefore drawn from the same lime-soda softening system that provides boiler feedwater. This portion of the supply is not filtered at Hoskins Mound but is drawn from the settling basin of the cold process softening plant.

HANDLING AND DISPOSAL OF BLEEDWATER DRAWN FROM THE MINES

The water which must be bled from the exhausted portions of the sulphur formations, in order to maintain circulation, may vary in temperature from atmospheric to 250°F., depending on the geological features of the dome and the elevation from which the water is drawn. This water contains large amounts of sulphides which make it highly corrosive and so toxic to marine life that it is necessary to remove these impurities fairly completely before discharging the water to waste.

Steel piping in bleed wells corrodes at a rapid rate and the volume of water produced decreases quickly. Recently wells have been equipped with cement-lined pipe and there are indications that this problem of corrosion has been eliminated. For surface gathering lines special corrosion-resistant materials, such as Admiralty, Muntz metal and asbestos pipe, have been used, but cast iron has proved to be the most economical. The original method of purification consisted in discharging the water downward through a packed scrubbing tower against an upward current of hot flue gases from the power plant. Hydrogen sulphide was liberated by the action of the carbon dioxide of the flue gas, and was discharged into the atmosphere. Excessive maintenance costs, due to scale deposition in the treating towers, led to the development of a new method which consisted of spraying the water into an open reservoir for liberation of free hydrogen sulphide and detention and mixture with large amounts of water containing dissolved oxygen to oxidize the sulphides to sulphates. The finally treated water is free of all toxic properties.

The possibility of re-using hot bleedwater or reclaiming its heat

has been studied since the beginning of mine operation. For several years heat was recovered by means of heat exchangers containing admiralty metal tubes. This process was inefficient and expensive to maintain because of scale deposition. During the past two years this water has been successfully reclaimed by mixing it directly with plant water at a temperature of about 355°F. and has constituted 40 per cent of the total mine water pumped into the producing wells. Rapid corrosion of the steel piping in the wells and the distribution system because of the sulphides and other acidic constituents has been an obstacle to such utilization of the bleedwater in the past. A study of this problem and extensive experiments have developed a treatment with lime, barium chloride and tri-sodium phosphate, which results in the deposition of a uniform protective scale. The treatment is closely controlled by means of chemical proportioning equipment. Subsequent savings due to recovery of heat and reduction in water requirements have been of considerable importance.

THE REMOVAL OF SILICA FROM WATER FOR BOILER FEED PURPOSES

The Ferric Sulphate and Hydrous Ferric Oxide Process

By M. C. Schwartz

INTRODUCTION

Probably all natural waters contain silica in varying concentrations and the presence of this impurity, which in general is to a large extent, if not almost completely, unaffected by conventional methods of water purification, can give rise to serious difficulties or inefficient operation in steam generating units (21).

NATURE OF SILICA IN WATER

It is beyond the scope of this paper to consider the nature of silica in natural waters except in the briefest manner. It has been conventional in representing the results of water analysis to consider silica as colloidal. Those investigators who have considered the problem experimentally have established the fact that silica can be, and is, present in the crystalloidal state (16, 23, 29, 32, 36, 43, 57, 66, 74, 94, 95). Unpublished results obtained by the author with Mississippi River water at Baton Rouge, La. corroborate this finding, and in the subsequent discussion of the removal of silica it is to be understood that crystalloidal silica is being considered. However, it is not to be assumed that colloidal silica, and more particularly colloidal silicates, do not occur in natural waters (27, 57, 105). Such occurrence undoubtedly exists, but it is reasonably certain that complete clarification will remove this form of siliceous material.

A paper to be presented before the meeting of the Joint Boiler Feed Water Research Committee at New Orleans, April 26, 1938. The author is Boiler Feed Water Fellow of the Institute of Industrial Research, Louisiana State University, Baton Rouge, La. The present paper refers to a portion of a program of boiler feedwater research being carried out by the Louisiana Steam Generating Corporation under the general direction of E. B. Powell, Stone and Webster Engineering Corporation, Boston, Mass.; with the coöperation of the Institute of Industrial Research, Louisiana State University; and, with the collaboration of S. T. Powell, Baltimore, Md.

There may still be present, however, sufficient residual silica to warrant its removal, in whole or in part, and it is such a problem that is here being considered.

CONVENTIONAL METHODS OF WATER PURIFICATION

Practically all of the chemical reagents used for coagulation or softening, or both, will remove small amounts of silica from water, especially if it so happens that high concentrations of chemicals are being used; instances of almost complete removal of silica have been reported. Silica removal under such circumstances has been incidental, and accidental. It may be safely said that current conventional methods of water purification are not to be relied upon for silica removal.

SILICATE SCALES

The occurrence of silica deposits on boiler heating surfaces and turbine blades has been known and studied for some time and the physical and chemical behavior of such deposits, in contrast with that of others, $CaCO_3$, $CaSO_4$, $Mg(OH)_2$ and the like, has made them of serious concern in most instances where they have appeared (6, 13, 16, 20, 22, 24, 25, 29, 33, 34, 39, 45, 46, 63, 69, 71, 72, 76, 85, 86, 90, 91, 92, 93, 96, 97, 99, 101, 103). But it is only comparatively recently, following the adoption of relatively high pressure steam (pressure higher than 450 lb./sq. in.) for power generating purposes, that silica in boiler feed water has been given very systematic study. The problem has been rendered particularly acute by the introduction of the high pressure, high rated capacity, noncondensing power plant using exclusively chemically treated natural water for boiler feed makeup.

THE LITERATURE ON THE REMOVAL OF SILICA

In considering the removal of silica from water it is convenient to divide the methods into the following classification (A) distillation (B) electro-osmosis (C) precipitation or adsorption (or both) and (D) anion exchange.

(A) Distillation is quite often not an economically satisfactory method for purifying water. Experimental data on either laboratory or commercial evaporators with reference to silica removal are practically non-existent, but it may be stated that complete removal is obtained except for that resulting from condenser leakage and

evaporator carryover. On a number of power plant evaporator installations the silica carryover has been surprisingly large. It is pertinent in this connection to mention the polemical subject of the volatility of silica in steam (28, 30, 64, 67, 68, 84, 98).

(B) The purification of water by electro-osmosis can hardly at this time be looked upon as commercially feasible on any very large scale. The development of this method has largely taken place on the continent. With respect to the removal of silica, the process is apparently capable of showing something about the nature of silica in water. Membranes of the electro-osmotic apparatus are considered to be impermeable to colloids so absence of any reduction in silica during the process is taken to indicate its colloidal nature (105). However, silica has been found in both the anode and cathode chambers which complicates the situation still further (31, 56, 62, 73). The experimental evidence for the removal of silica by this type of apparatus is apparently inconclusive (7, 70).

(C) The removal of silica from water by precipitation of insoluble silicates is for the most part unsatisfactory due to the appreciable solubility of most silicates. Silica and the silicates of all the metals except the alkalies are considered insoluble, but an examination of data available indicates that ordinarily sufficient silica is left in solution to render the method unsatisfactory (8, 9, 26, 37, 44, 50, 51, 65, 66, 102, 106). However, by use of the principle of decreasing the solubility by adding an excess of precipitating reagent, it is possible to obtain results by precipitation of insoluble silicates (2, 4, 11, 12, 14, 17, 18, 19, 20, 38, 42, 47, 49, 57, 58, 59, 60, 75, 77, 82, 83, 88, 89, 93, 94, 95). Factors which should be taken into consideration are those of temperature (20, 41, 57, 90, 92, 94), concentration of silica (20, 92), reaction time (57), pH (18, 40, 78, 83, 86, 87, 94), and ionic composition of the solution (9, 11, 90, 94). It is practically impossible to discuss removal of silica by adsorption without simultaneously considering precipitation, since both may take place in actual procedure. The distinction between precipitation and adsorption is here made on the basis of compound formation in the former case, and adsorption following the Freundlich adsorption isotherm in the latter. On such a distinction probably most methods of silica removal are to be considered as adsorption methods (40, 48, 53, 78, 87). For example, the adsorptive properties of hydrous ferric oxide are well known (5, 10, 15, 35, 52, 54, 55, 61, 80, 81, 100, 104, 107).

(D) Anion exchange is a new development in water purification

(1). No definite experimental evidence has been yet published demonstrating the removal of silica by anion exchange.[1]

EXPERIMENTAL APPARATUS AND PROCEDURE

For the studies from which the present data are taken the silica concentrations were determined with a 100 mm. Hellige colorimeter using a special glass standard carefully calibrated against prepared silica standards. The general technique followed that described in a previous paper, except that, as phosphates were not present to a practically measurable extent, the provisions for phosphate removal were omitted (79). The reactions of the silica removal process were in general carried out in 1 liter beakers equipped with a convenient mixing apparatus equipped with stainless steel blades and stationary rods. A similar mixing apparatus was used for 30 liter samples. Alkaline reagents were kept in hard rubber bottles, and other reagents in Pyrex bottles to prevent contamination from solution of silica from the glassware. For hot process tests monel beakers were used. No particular attempt was made to maintain definite temperatures of reaction for experiments carried out at room temperature since the results were not sensitive to moderate temperature changes. For cold process tests average mixing or reaction times were 30 minutes followed usually by 1 hour settling. For hot process tests the mixing time was decreased to 3 minutes followed by 15 minutes settling. The effect of varying the mixing time and settling time was investigated. Reagents were usually added simultaneously, although varying rates of addition were also investigated. pH measurements were taken with hydrogen-saturated calomel electrodes in the earlier stages of investigation and, later on when conditions were rather well established, by liquid colorimetric standards.

Water used in the experimental work on removal of silica was for the most part that of the Mississipi River as obtained at Baton Rouge, Louisiana by the Louisiana Steam Generating Corporation. Several other waters, however, have been investigated. The average concentration of dissolved or crystalloidal silica in the Mississippi River is about 7 parts per million. In fact the silica concentration of the river water usually remains within close approximation to 7 parts per million, rarely varying by more than 2 parts per million,

[1] Private communication, Dept. Scientific and Industrial Research, England. Feb. 1937.

in marked contrast with the turbidity, alkalinity, and total hardness which vary within wide limits.

In the course of the investigation, practically every possible combination of water purifying reagents within economical bounds, and some which were not economically feasible, were tried. These reagents which were used singly or in various combinations, for cold process treatment, included: aluminum chloride, aluminum sulfate, barium aluminate, barium bicarbonate, barium carbonate, barium chloride, barium hydroxide, calcium carbonate, calcium chloride,

TABLE 1

Cataphoretic study of clarification of natural water

Mississippi River water—Baton Rouge, La.

$Fe_2(SO_4)_3$	FLOCCULATION TIME	CHARGE	CATAPHORETIC VELOCITY
p.p.m.	*seconds*		*mμ/sec./v./cm.*
50	45	−	3.6
100	15	−	3.1
200	10	+	1.2
FeO_3			
p.p.m.			
50	10	−	4.1
100	0	−	1.8
200	140	+	3.1
COLLOIDAL $Fe_2O_3 \cdot xH_2O$			
p.p.m.			
50	25	−	4.1
100	10	−	2.6
200	175	+	2.6

calcium hydroxide, carbonic acid, ferric chloride, ferric and ferrous sulfate, hydrochloric acid, hydrous aluminum oxide, hydrous ferric oxide, hydrous ferrous oxide, magnesium aluminate, magnesium carbonate, magnesium oxide, magnesium sulfate, sodium aluminate, sodium carbonate, sodium hydroxide and zinc sulfate. Reagents tried for hot process treatment included aluminum sulfate, calcium hydroxide, ferric and ferrous sulfate, magnesium sulfate, sodium carbonate, trisodium phosphate. Both chemically pure and commercial grade chemicals were tried where available. Limitation of space will not permit inclusion of all data. Therefore, in view of

their present importance and as development work on none of the other reagent processes has as yet been carried to an equally definite stage, experimental results are now presented only for the use of ferric sulphate and hydrous ferric oxide.

EXPERIMENTAL RESULTS

CLARIFICATION VS. SILICA REMOVAL

Since in many instances silica has been assumed to exist in the colloidal state, it is necessary to consider the relationship between clarification and silica removal. Cataphoretic studies, as shown by the data in table 1 and figure 1, demonstrate that clarification takes place before reversal of charge on the floc particles consisting of precipitated chemicals and suspended turbidity. Even upon addition of sufficient chemical to cause a reversal of charge on the floc particle there may be practically no change in silica concentration if clarification takes place in the acid region of pH, which was the case in these studies. It is quite interesting to note the close agreement between reversal of floc particle charge and zero flocculation time (time required for formation of visible floc particles with Tyndall beam illumination).

EFFECT OF pH

At least for the particular waters covered by this present research, silica removal with ferric sulphate is best accomplished in the alkaline region of pH. Accordingly, because of the acidic nature of ferric sulfate, the process has required the addition of alkaline reagents except where sufficient alkalinity obtains in the water initially. As the data of table 2 and figure 2 show, an optimum use of chemical has been secured at a pH in the neighborhood of 9. After determination of the most favorable pH, subsequent comparative studies were conducted with this factor held constant.

EFFECT OF REACTION TIME

The reaction involved in silica removal with ferric sulphate is practically instantaneous, governed essentially by the rate of chemical dispersion. However, as will be seen from the experimental data given in table 3, overall results improve slightly with increasing reaction time and, while the actual time allowed will often be fixed by practical plant limitations, in general a mixing time allowance of one-half hour or more is advantageous.

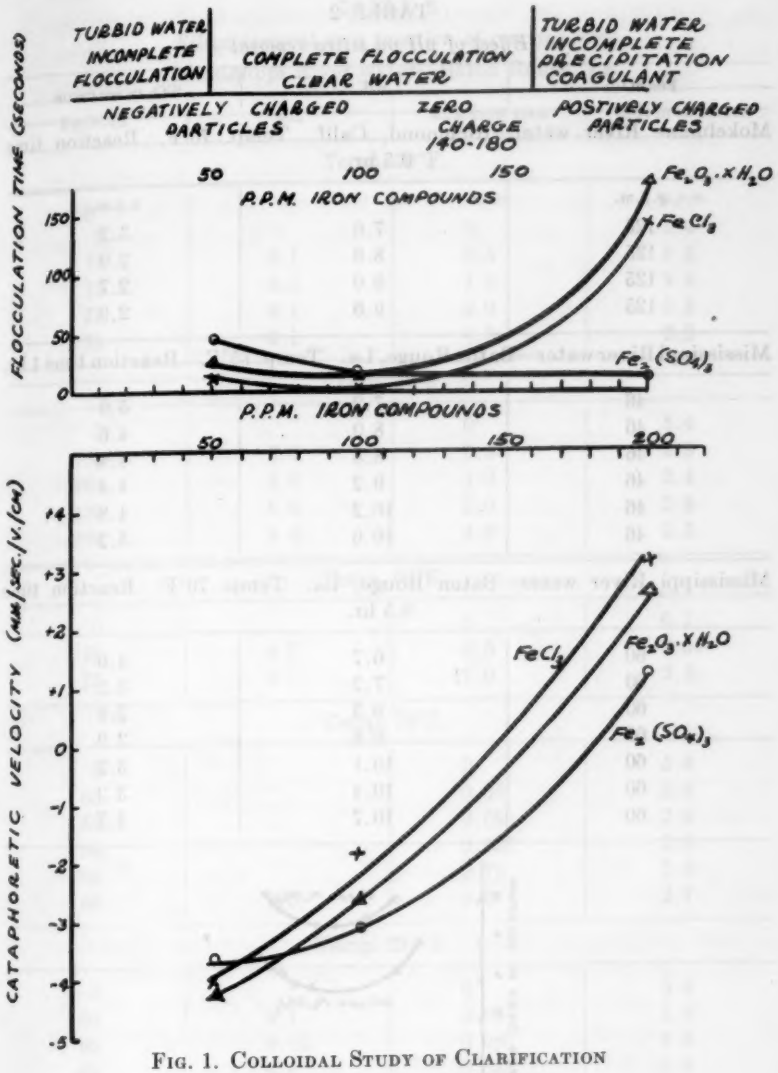


FIG. 1. COLLOIDAL STUDY OF CLARIFICATION

EFFECT OF TEMPERATURE

Increasing the temperature at which the silica is removed with ferric sulfate results in decreasing efficiency of a given chemical dosage. However, the effect is not appreciable until the differences obtained in "cold process" and "hot process" treatment are considered. Table 4 presents data for the effect of temperature.

TABLE 2

Effect of pH on silica removal

$Fe_2(SO_4)_3$	pH	SiO_2 IN SOLUTION
Mokelumne River water—Richmond, Calif. Temp. 70°F. Reaction time 0.5 hr.		
p.p.m.		*p.p.m.*
125	7.6	3.2
125	8.6	2.9
125	9.0	2.7
125	9.6	2.9
Mississippi River water—Baton Rouge, La. Temp. 75°F. Reaction time 1 hr.		
46	7.2	5.0
46	8.0	4.6
46	8.8	4.4
46	9.2	4.4
46	10.2	4.8
46	10.6	5.2
Mississippi River water—Baton Rouge, La. Temp. 70°F. Reaction time 0.5 hr.		
60	6.7	4.0
60	7.2	3.2
60	9.3	2.8
60	9.8	2.9
60	10.1	3.2
60	10.4	3.3
60	10.7	3.7

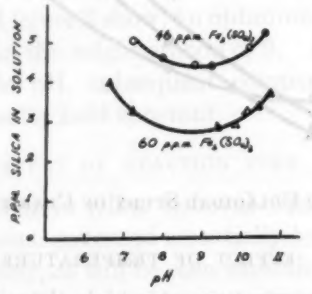


FIG. 2. EFFECT OF pH ON SILICA REMOVAL

ADSORPTION STUDIES

Experimental work designed to distinguish between compound formation and adsorption has seemed to demonstrate rather conclu-

TABLE 3

Silica removal as a function of reaction time

Mississippi River water—Baton Rouge, La.

$Fe_2(SO_4)_3$	pH	REACTION TIME	SiO_2 IN SOLUTION
Temp. 70°F.			
p.p.m.		hours	p.p.m.
0		0	5.4
75	9.1	0.5	2.5
75	9.1	1.0	2.4
75	9.1	2.0	2.3
75	9.1	4.0	2.2
Temp. 70°F.			
0		0	5.4
109[1]	7.9	0.5	2.8
109	8.8	1.0	2.4
109	8.8	2.0	2.3
109	9.4	4.0	2.3
Temp. 90°F.			
0		0	6.7
75	8.7	0.5	3.65
75	8.7	17.0	2.8
Temp. 70°F.			
0		0	5.5
65		0.05	2.9
65		0.083	2.9
65		0.033	2.9
65		0.75	2.9
65	9.0	2.0	2.7
Temp. 212°F.			
0		0	5.5
65	9.1	0.05	3.4
65	9.15	0.083	3.6
65	9.1	0.033	3.8
65	9.2	0.75	3.8
65	9.3	2.0	3.8

[1] P.P.M. hydrous ferric oxide as ferric sulfate.

sively that the latter is the mechanism by which silica is removed from solution by ferric sulfate. The more important data and observations upon which this opinion is based follow:

In adsorption the importance of the nature of the adsorbing surface is well known; the effect of the surface condition can not fail to impress anyone doing research in silica removal.

The chemical dosages required represent at least a five to ten fold excess over the stoichiometric needs for formation of metasilicates, although to be sure there is no definite reason for assuming the existence of silica as the simple metasilicate ion.

TABLE 4

Effect of temperature on silica removal

$Fe_2(SO_4)_3$	pH	TEMPERATURE	REACTION TIME	SiO_2 IN SOLUTION
Mississippi River water—Baton Rouge, La.				
p.p.m.		*°F.*	*hours*	*p.p.m.*
75	8.7	80	1	3.0
75	8.7	120	1	3.0
Mississippi River water—Baton Rouge, La.				
65	9.1	65	0.5	2.7
65	9.1	212	0.05	3.9
65	9.1	70	0.5	2.8
65	9.0	212	0.05	3.9
65	9.0	70	2.0	2.7
65	9.3	212	2.0	3.8
Mokelumne River water—Richmond, Calif.				
125	9.0	70	0.5	2.7
125	9.0	212	0.05	3.9

As to be expected from mass-action behavior in adsorption phenomenon, the effect of the initial silica concentration is very significant in the silica removal reaction, the efficiency of a given chemical charge decreasing markedly with decreasing initial silica concentration.

The experimental results given in table 5 fit a Freundlich adsorption isotherm as is shown by figures 3, 4, and 5.

The influence of ionic composition on silica removal with ferric sulfate is demonstrated by the difference between the results obtained with a natural river water and a well water. Ferric sulfate will not precipitate in the latter, even upon addition of alkali, due to the

almost complete absence of calcium and magnesium ions and other polyvalent cations. On addition of small amounts of lime, ferric sulfate will precipitate with alkali.

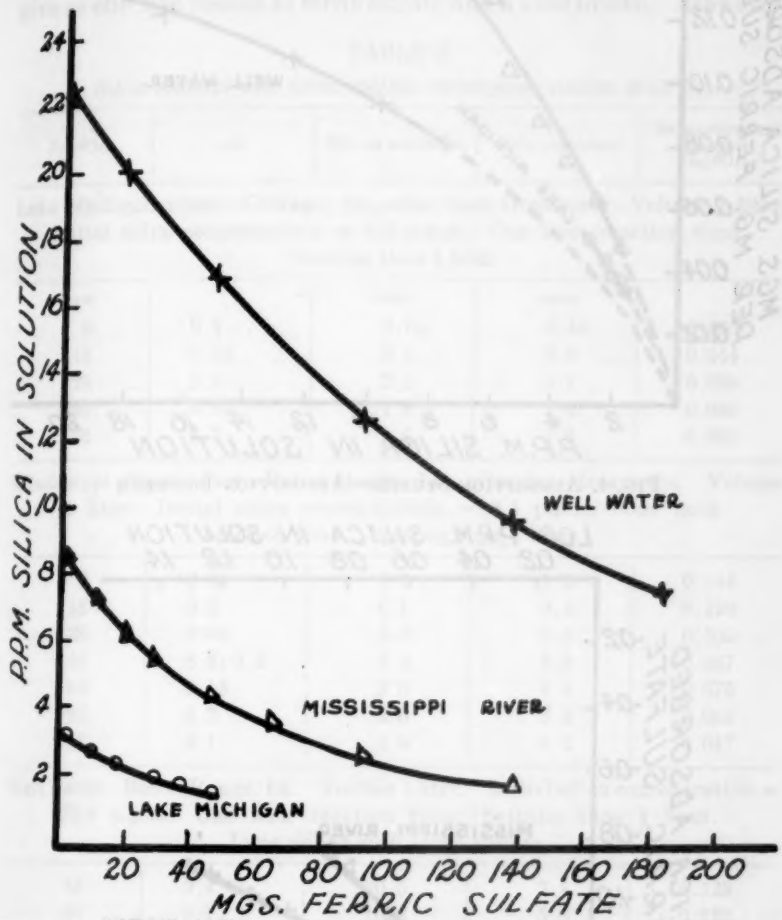


FIG. 3. ADSORPTION STUDIES—EFFECT OF INITIAL SILICA CONCENTRATION ON SILICA REMOVAL

COMPARATIVE STUDY OF FERRIC SULFATE AND HYDROUS FERRIC OXIDE

In some instances the introduction of the sulphate radical through use of ferric sulfate will be undesirable because of the increase in total dissolved solids. In such cases the supplementary use of hydrous ferric oxide, prepared from ferric sulfate and sodium hydroxide for example, and washed reasonably free from sodium sulfate, may be

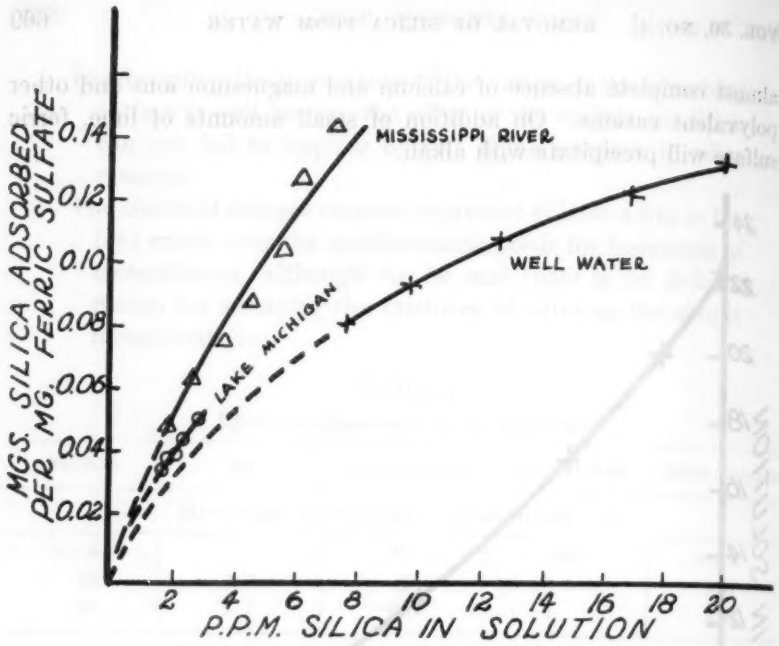


FIG. 4. ADSORPTION STUDIES—ADSORPTION ISOTHERM

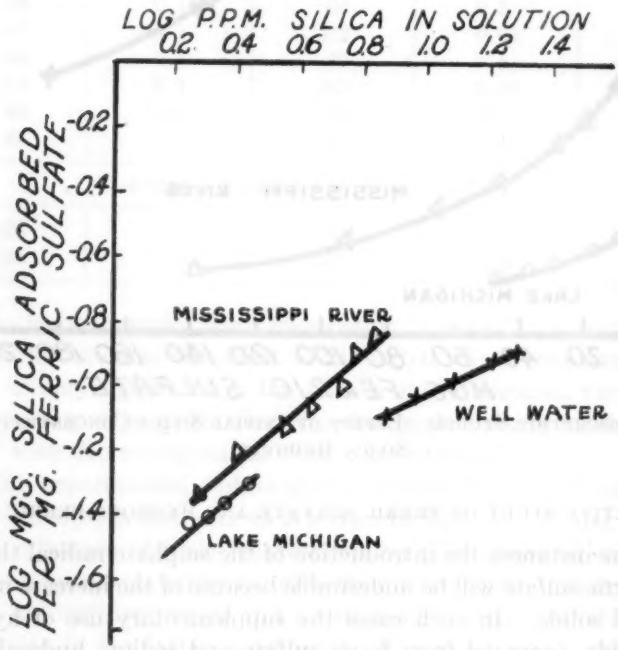


FIG. 5. ADSORPTION STUDIES—LOG LOG PLOT OF ADSORPTION ISOTHERM

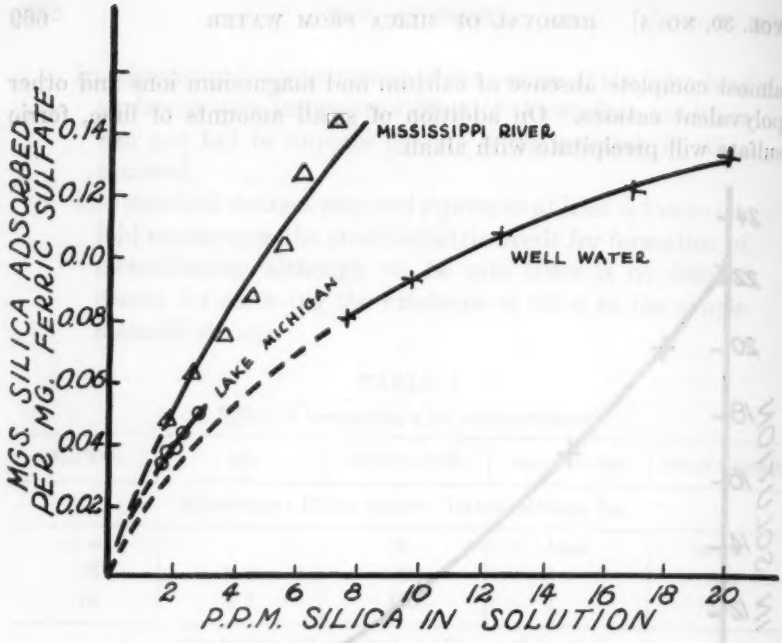
worth consideration. The use of the by-product, sodium sulfate, for base exchange softening may make the economics of the process more favorable. So far, the use of hydrous ferric oxide does not give as effective results as ferric sulfate and a base in situ. However,

TABLE 5

Silica removal with ferric sulfate—adsorption studies at 75°F.

$Fe_2(SO_4)_3$	pH	SiO_2 IN SOLUTION	SiO_2 ADSORBED	SiO_2 ADSORBED PER MGM. $Fe_2(SO_4)_3$
Lake Michigan water—Chicago, Ill., after lime treatment. Volume 1 liter. Initial silica concentration = 3.2 p.p.m. One hour reaction time. Settling time ½ hour				
mgm.		*mgm.*	*mgm.*	
9	9.1	2.75	0.45	0.050
18	9.05	2.4	0.8	0.044
28	9.1	2.1	1.1	0.039
37	9.05	1.8	1.4	0.038
46	8.7	1.6	1.6	0.035
Mississippi River water—Baton Rouge, La., after lime treatment. Volume 1 liter. Initial silica concentration = 8.4 p.p.m. One hour reaction time. Settling time ½ hour				
9	9.35	7.1	1.3	0.144
18	9.3	6.1	2.3	0.128
28	9.05	5.5	2.9	0.103
46	8.8; 9.2	4.4	4.0	0.087
64	9.15	3.6	4.8	0.075
92	9.2	2.6	5.8	0.063
138	9.1	1.9	6.5	0.047
Well water—Baton Rouge, La. Volume 1 liter. Initial silica concentration = 22.4 p.p.m. One hour reaction time. Settling time ½ hour. Lime added with ferric sulfate				
18	9.4	20.0	2.4	0.133
46	9.1	16.8	5.6	0.122
92	8.8	12.6	9.8	0.106
138	8.7	9.6	12.8	0.095
184	8.9	7.6	14.8	0.081

it is quite possible that, by further research, the effectiveness of hydrous ferric oxide can be increased above that presented in the following data. Acid treatment of the spent floc removes most of the adsorbed silica with some loss of material; after washing, the



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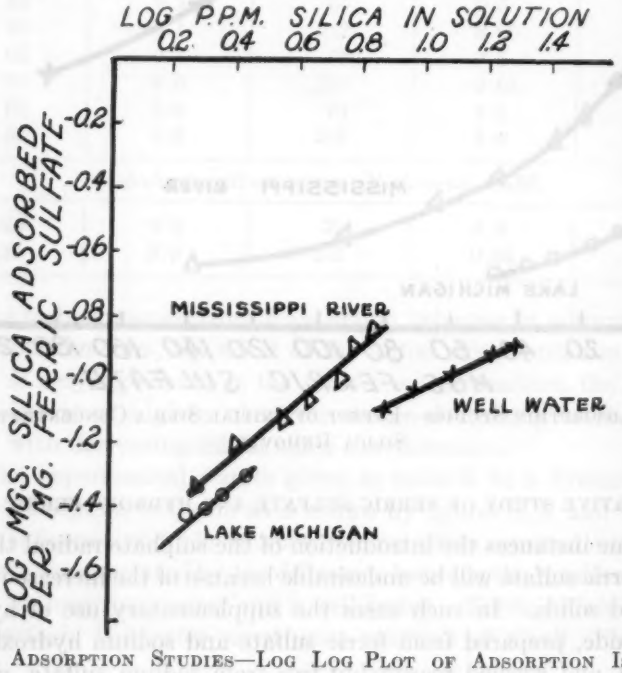

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mgm.		*mgm.*	*mgm.*	
9	9.1	2.75	0.45	0.050
18	9.05	2.4	0.8	0.044
28	9.1	2.1	1.1	0.039
37	9.05	1.8	1.4	0.038
46	8.7	1.6	1.6	0.035
Mississippi River water—Baton Rouge, La., after lime treatment. Volume 1 liter. Initial silica concentration = 8.4 p.p.m. One hour reaction time. Settling time ½ hour				
9	9.35	7.1	1.3	0.144
18	9.3	6.1	2.3	0.128
28	9.05	5.5	2.9	0.103
46	8.8; 9.2	4.4	4.0	0.087
64	9.15	3.6	4.8	0.075
92	9.2	2.6	5.8	0.063
138	9.1	1.9	6.5	0.047
Well water—Baton Rouge, La. Volume 1 liter. Initial silica concentration = 22.4 p.p.m. One hour reaction time. Settling time ½ hour. Lime added with ferric sulfate				
18	9.4	20.0	2.4	0.133
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it is quite possible that, by further research, the effectiveness of hydrous ferric oxide can be increased above that presented in the following data. Acid treatment of the spent floc removes most of the adsorbed silica with some loss of material; after washing, the

regenerated floc can be used again for further silica removal. Such a procedure will of course work best where natural turbidity, calcium carbonate sludges, and the like are absent. Data are presented in tables 6 A and 6 B.

SUMMARY

The reduction and removal of silica can be accomplished by the use of salts of ferric ion, particularly the sulfate, and alkaline compounds of the alkaline earth and alkali metals. The optimum reduction and removal of silica for the waters investigated are obtained in the pH range 8.5–9.5.

The desilification may be carried out in conjunction with cold process or hot process chemical treatment for softening. If the process of silica reduction and removal is carried out in conjunction with cold or hot process softening, the ferric iron compound may be added along with lime alone; or with lime and soda ash; or with lime and sodium aluminate; or with lime, sodium aluminate, and soda

TABLE 6 A

A comparative study of silica removal using ferric sulfate, newly prepared hydrous ferric oxide, and acid treated regenerated hydrous ferric oxide

A, ferric sulfate; B, new hydrous ferric oxide; C, acid treated regenerated hydrous ferric oxide

	$Fe_2(SO_4)_3$	pH	SiO_2 IN SOLUTION
	p.p.m.		*p.p.m.*
A	49.3	8.4	3.2
A	73.9	9.4	2.9
A	98.5	9.65	2.5
B	48.7	9.5	4.9
B	97.4	9.5	4.3
B	146.1	9.5	3.65
B	194.8	9.5	3.4
C	48.7	9.7	5.4
C	97.4	9.6	4.7
C	146.1	9.3	4.1
C	197.0	9.2	3.7

Mississippi River water—Baton Rouge, Louisiana.
Initial concentration of silica in solution 6.0 p.p.m.
Tests on 30 liter batches of lime softened water.
Reaction time 30 minutes; settling time 1 hour.

ash; or with lime, soda ash, and barium salts; or with sodium phosphate. Or, it may be added in any case after softening by reagents

TABLE 6 B

Silica removal with hydrous ferric oxide and ferric sulphate

A, ferric sulfate; B, new hydrous ferric oxide; C, acid treated regenerated hydrous ferric oxide

INITIAL CONCENTRATION, SiO_2 IN SOLUTION	EQUIVALENT $Fe_2(SO_4)_3$			NaOH	ROUND	pH	SiO_2 IN SOLUTION
	A	B	C				
p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*			*p.p.m.*
6.2	26	81		45	1	9.3	3.7
6.0	29	91		50	2	7.5	3.4
5.8	29	91		50	3	7.5	3.2
6.0	29	91		50	4	7.5	3.3
5.8	29	91		50	5	7.7	4.2
5.6	29	91		50	6	7.5	3.4
All sludge from rounds 1–6 treated with 3.57 grams H_2SO_4 and re-used in rounds 7–11							
5.8	16	49	97	27	7	8.9	3.2
5.8	18	55	110	30	8	8.8	2.9
5.9	18	55	110	30	9	8.75	2.8
5.9	18	55	110	30	10	8.7	2.6
5.8	18	55	110	30	11	9.0	2.6
Rounds 7–11 partly sludged. All sludge so collected treated with 3.57 grams H_2SO_4 and re-used in rounds 12–15							
6.0	18	55	137	30	12	8.8[1]	2.5
5.8	18	55	137	30	13	8.8[2]	2.5
5.9	18	55	137	30	14	9.0[3]	2.5
6.0	18	55	137	30	15	9.0[4]	2.5
6.0	18	55	137	30	15	8.4[5]	2.5

Notes: [1]4 hours settling time; [3]3 hours settling time, [2]2 hours settling time; [4]1 hour settling time; [5]2 days settling time.

Rounds 2–6 did not have proper pH for optimum silica removal.

Mississippi River water—Baton Rouge, Louisiana.

Tests on 30 liter batches of lime softened water.

Reaction time 30 minutes; settling time 1 hour unless otherwise stated.

All sludge retained each round 1–6, 12–15 and partially retained for rounds 7–11.

such as those enumerated above, either alone or in conjunction with alkaline compounds of the alkaline earth and alkali metals, or with barium salts, or with barium salts and alkaline reagents so that the

optimum pH range is maintained. Any coagulant normally used in water purification may be included in the treatment provided only that for optimum results the proper pH range be maintained.

The treatment may be carried out independently and practically exclusive of any softening of the natural water by using the ferric iron compound alone or with alkaline reagents, or with barium salts, or with barium salts and alkaline reagents, maintaining in the particular case optimum pH conditions for silica reduction and removal. If the process is carried out alone it may be at atmospheric temperatures or at elevated temperatures.

Silica removal may also be effected before softening. If softening by base exchanging compounds is to follow, however, only the non-siliceous base exchange compounds should be used as the siliceous compounds tend to give up silica to a low silica water. On the other hand, the ferric iron treatment for silica removal should not normally follow base exchange softening due to the fact that multivalent positive ions required for proper coagulation of the ferric iron compounds are then lacking.

The use of barium salts along with the ferric iron compounds, in this case the sulphate, with or without additional alkaline reagents, will make it possible to avoid increase in the total amount of dissolved solids, or to raise the total but slightly beyond that in the natural water initially, principally because the barium ion combines with the sulphate ion of the added ferric compound.

The use of ferric iron compounds and alkaline reagents to produce hydrous ferric oxide in situ is more efficient for silica removal than the use of hydrous ferric oxide prepared separately from the process of water treatment and with the soluble solids removed. The use of the hydrous ferric oxide prepared separately and with the soluble solids removed to the practical extent desired, does however also permit avoidance of appreciable increase in the total of dissolved solids.

If it is desired to re-use the sludge after treatment with the ferric iron compounds, addition of acid in the pH range 2–3, or alkali in the pH range 11 or higher, followed by subsequent washing of the remaining sludge will permit further reduction and removal of silica from the natural water by this regenerated sludge. The removal capacity of the re-used sludge is of course less than that of the original material. It is important to observe that any cations added (other than those of the alkali metals) for the purpose of removing silica

from boiler lead water, should themselves be completely precipitated from solution in the process.

CONCLUSION

Like other problems of water purification, the removal of silica is largely governed by the chemical characteristics of the water under consideration and, therefore, with our present state of knowledge, for every untried water supply, requires individual experimentation.

Removing silica from water for boiler feed purposes in actual commercial practice has only recently begun and it is expected that succeeding years will show marked development in the art.

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INTERCRYSTALLINE CRACKING IN BOILER STEEL

By W. C. Schroeder, A. A. Berk, and C. H. Fellows

In 1934, Powell (1) estimated the cost of repairs and replacement on boilers damaged by intercrystalline cracking or embrittlement during the preceding four years at approximately 200,000 dollars per year. In spite of this outlay no extensive experimental work was in progress on this specific problem, although a related investigation concerning the solubility of sodium sulphate in boiler water salines was under way at the Bureau of Mines. This situation existed because many operators believed a satisfactory solution to the difficulty was available if conditions believed to be correct were maintained in boilers. These conditions which had been accepted as correct involved principally the maintenance in the boiler water of such concentrations of sodium sulphate and alkalinity that the ratios suggested by the A.S.M.E. for the prevention of embrittlement were satisfied. These ratios it will be recalled were based upon data gathered from boilers throughout the country and were later supported by the important pioneer work of Parr and Straub. On the other hand many competent engineers believed that the use of sodium sulphate for protection was based on contradictory operating data.

The solubility studies at the Bureau of Mines under the auspices of the Joint Research Committee on Boiler Feedwater Studies attempted to establish an accurate basis for the use of sodium sulphate

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to prevent embrittlement. During this work it became apparent that the existing knowledge concerning the cause and prevention of intercrystalline cracking was not complete.

The investigators and directing committee of this research work appreciating the need of information more fundamental than that then available instituted a program of study designed to answer the following questions:

1. What factors were involved in the development of embrittlement or intercrystalline cracks in boilers?

2. Were the protective means in current use, namely the maintenance in the boiler water of prescribed ratios of sodium sulphate to alkalinity, adequate for preventing this trouble?

3. If this protective measure was not satisfactory, what measures could be used to inhibit such cracking?

As the result of intensive laboratory study, the investigators are in a position to answer these questions as follows:

1. Embrittlement or intercrystalline cracking in boilers is caused by selective corrosion of the metal at the grain boundaries. This is brought about generally through the action of sodium hydroxide-sodium silicate solutions, while the steel is under either internal or external stress.

2. Neither sodium sulphate nor other inorganic salts ordinarily present in boiler waters are, for all conditions completely effective in the inhibition of intercrystalline cracking.

3. A number of organic compounds have been discovered, which in the laboratory accelerated tests at pressures up to 550 pounds per square inch (and in a limited number of actual service operations at lower pressures) have stopped the selective corrosion reaction and prevented failure by intercrystalline cracking.

The laboratory experimentation on which these answers are based has already been described in a series of technical publications by the investigators. The present paper will survey this work in a broad manner and present the basic ideas concerning the occurrence and the means of preventing intercrystalline cracking.

OCCURRENCE OF INTERCRYSTALLINE CRACKS

Normal low-carbon steel does not crack in an intercrystalline manner when it is stressed in tension at any temperature in the boiler water range unless it is in a certain chemical environment. This is true whether the applied stress acts for a very short time or

for a period of years. When predominantly intercrystalline cracks were observed in boiler seams and tube ends three known mechanisms were suggested to explain this specific type of failure. In the first, the diffusion of hydrogen into the metal was believed responsible for brittleness, and perhaps intercrystalline cracking; in the second, these same results were thought to be due to corrosion fatigue; and in the third, to selective corrosion of the grain boundaries.

Since methods for preventing hydrogen brittleness on the one hand and corrosion fatigue on the other vary widely from those that might prevent selective corrosion, it was necessary to study the fundamental mechanisms of all three to determine how cracking might be most effectively inhibited. Certain factors concerning each will be reviewed briefly.

Hydrogen Brittleness. It is a well-known fact that hydrogen introduced into steel, for example by acid pickling, will make the metal brittle. A considerable number of experiments has been run to compare this effect, at room temperature and at elevated temperature, with the action of solutions that produce intercrystalline cracking. Specific differences between the effect on metals of the gas and of solutions are as follows:

(1) Electrolytic hydrogen will not materially lower the tensile load-carrying ability of steel specimens; whereas certain solutions, representative of concentrated boiler waters, cause a fifty per cent reduction.

(2) Electrolytic hydrogen has not been found to produce intercrystalline cracks at boiler temperatures.

(3) The reactions of solutions on steel to produce hydrogen do not correlate directly with their effect on the load-carrying ability of the steel.

(4) Specimens immersed in certain solutions will not crack if hydrogen is evolved at the surface, but will show intercrystalline cracks in the same solution when oxygen is evolved at the surface.

At the present time, it must be concluded that the experimental evidence points away from the idea that hydrogen plays an important part in the grain-boundary cracking of boiler steel.

Corrosion Fatigue. Steel will indefinitely endure a constant stress somewhat above its yield point, but if the stress instead of being steady is repeated or reversed the steel will fail. The tendency toward such fatigue failure is greatly increased by any notch or other irregularity in the metal surface. When the notch is produced by

chemical attack the process leading up to failure is referred to as corrosion fatigue.

A number of investigators have believed that intercrystalline failure was a special case of corrosion fatigue. McAdam (2) thought it could be produced even in fairly dilute solutions of sodium hydroxide if the stress were high, the frequency cycle low, corrosion slight, and if there were very little accumulation of corrosion products. His corrosion fatigue work at room temperature, however, did not yield this type of failure.

Holzhauer (3) and Schroeder and Partridge (4), in extensive fatigue tests at temperatures in the boiler range, failed to secure intercrystalline cracks. Furthermore, some of the later work on this research

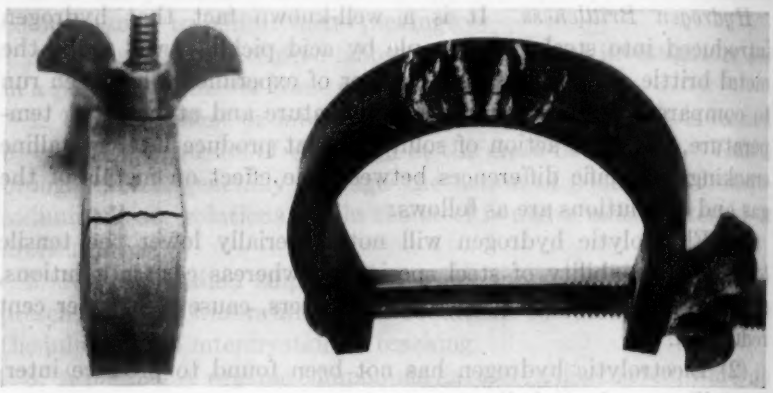


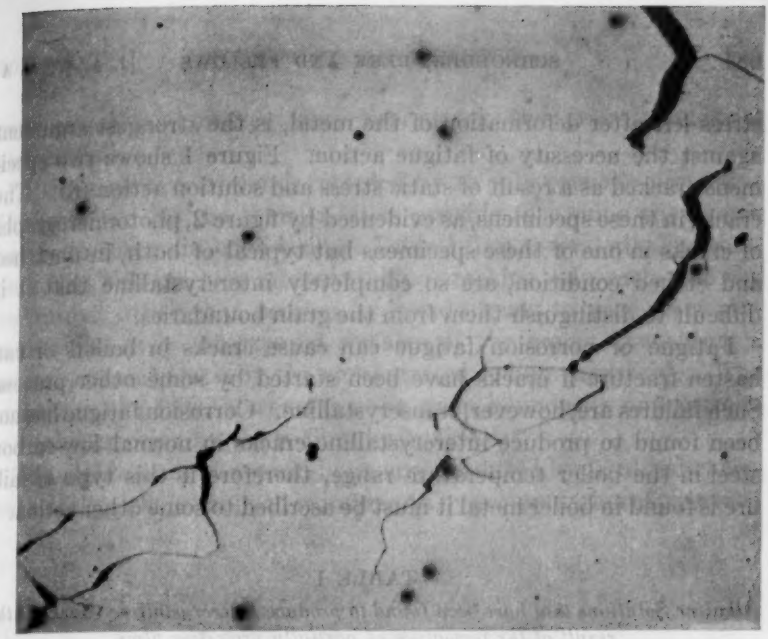
FIG. 1. CRACKING PRODUCED WITHOUT FATIGUE ACTION

Left: In sodium nitrate solution containing a small amount of manganous sulfate.

Right: In sodium hydroxide solution containing a small amount of sodium nitrate.

project has indicated that rotating beam fatigue tests at 250 C. (482 F.) in which the specimens were in contact with sodium hydroxide and sodium hydroxide-sodium silicate solutions have not produced intercrystalline cracks. Ruttman (5) after an extensive survey stated that "despite great efforts it has not been possible to produce intercrystalline fractures, as they appear in boilers, by pure oscillating stresses."

Perhaps the ease with which intercrystalline cracks can be secured under static applied stress, or more simply under residual internal



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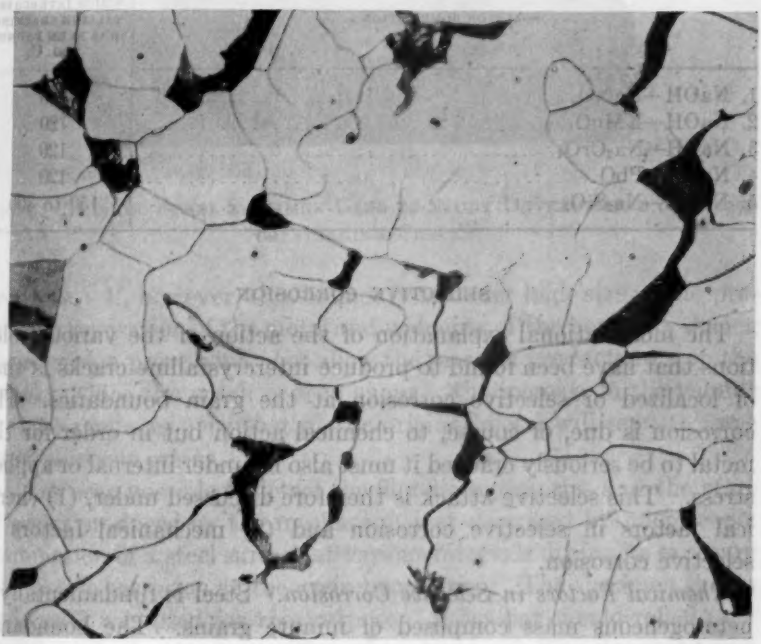

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FIG. 2. INTERCRYSTALLINE NATURE OF CRACKS PRODUCED IN SODIUM HYDROXIDE SOLUTIONS CONTAINING A SMALL AMOUNT OF SODIUM NITRATE. MAGNIFICATION—500×

stress left after deformation of the metal, is the strongest argument against the necessity of fatigue action. Figure 1 shows two specimens cracked as a result of static stress and solution action (6). The cracks in these specimens, as evidenced by figure 2, photomicrographs of cracks in one of these specimens but typical of both, in unetched and etched condition, are so completely intercrystalline that it is difficult to distinguish them from the grain boundaries.

Fatigue or corrosion fatigue can cause cracks in boilers or can hasten fracture if cracks have been started by some other process. Such failures are, however, transcrystalline. Corrosion fatigue has not been found to produce intercrystalline cracks in normal low-carbon steel in the boiler temperature range, therefore if this type of failure is found in boiler metal it must be ascribed to some other action.

TABLE I

Alkaline Solutions that have been found to produce Intercrystalline Cracks as the result of the formation of partially protective films

SOLUTION COMPOSITION	TEMPERATURES AT WHICH INTERCRYSTALLINE CRACKING HAS BEEN FOUND, DEG. C.
1. $NaOH—NaNO_3$	120
2. $NaOH—KMnO_4$	120
3. $NaOH—Na_2CrO_4$	120
4. $NaOH—PbO$	120
5. $NaOH—Na_2SiO_3$	150 to 300

SELECTIVE CORROSION

The most rational explanation of the action of the various solutions that have been found to produce intercrystalline cracks is that of localized or selective corrosion at the grain boundaries. The corrosion is due, of course, to chemical action but in order for the metal to be seriously cracked it must also be under internal or applied stress. This selective attack is therefore discussed under, (1) chemical factors in selective corrosion and (2) mechanical factors in selective corrosion.

Chemical Factors in Selective Corrosion. Steel is fundamentally a heterogeneous mass composed of minute grains. The boundaries between these grains represent material that differs physically or chemically or in both respects from the grains themselves. Ordi-

nary corrosion, however, does not attack the grain boundaries preferentially.

If the general corrosion is retarded by an only partially protective film produced by the solution, it is possible to confine the attack largely to the grain boundaries. Table I lists several alkaline solutions that will produce intercrystalline cracking. In each case the constituent other than sodium hydroxide tends to produce a protective film over the exposed surfaces of the grains, preventing a general surface attack by the concentrated sodium hydroxide. The protective film fails, however, at the grain boundaries and permits localized corrosion by the sodium hydroxide.

The slight notch at a grain boundary produced by localized chemical attack might be stopped in its growth by accumulation of corrosion

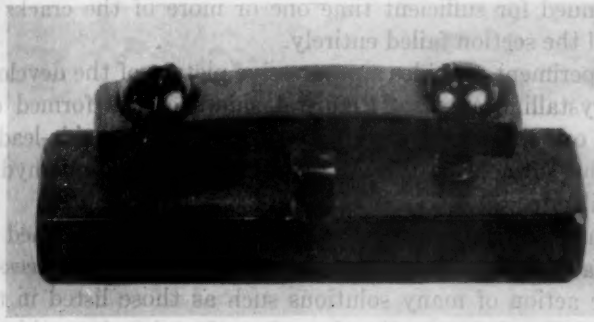

FIG. 3. POLISHED STEEL SPECIMEN USED TO STUDY DEVELOPMENT OF INTERCRYSTALLINE CRACKS

products. If, however, this boundary is under high stress, the progressive separation of the metal and widening of the boundary during the corrosion process may not allow the reaction products to stop the attack. Once the notch is deep enough, the increase in the volume of these products over that of the original metal will tend to force apart adjacent grains.

It has been possible to detect the film discontinuities and the start of cracks produced by the mechanism just described by microscopic examination of a steel surface at various intervals during its exposure to selective corrosion at the grain boundaries. The specimen shown in figure 3 was used for this purpose. It is a bar of cold-rolled steel $\frac{1}{2} \times \frac{1}{4}$ by 3 inches bent over the center bar by pulling down the two bolts at the ends.

For a test the top surface of this specimen was polished for microscopic observation. Drawing down the end bolts then bent it into the position shown in the figure and created a high stress in the polished surface. This treatment produced slip lines, as shown in figure 4, that remained clearly evident during the entire test. The specimen was immersed in a test solution and was removed for microscopic examination at periods ranging from 1 to 12 hours.

The solution quickly formed a thin, blue oxide coating readily visible to the eye. Under the microscope at 500 diameters, as seen in figure 4, the top surface began to show rather broad white lines that were found to coincide with the grain boundaries. After further solution attack, short black lines developed in the center of the white ones, and some of these joined together to form the more or less extended cracks seen in the photomicrograph. If the solution action was continued for sufficient time one or more of the cracks would grow until the section failed entirely.

This experiment provides a progressive picture of the development of intercrystalline cracks. Figure 4 shows cracks formed on the surface of one specimen by solutions of sodium hydroxide-lead oxide, and on the surface of another by solutions of sodium hydroxide-sodium silicate.

To demonstrate that a partially protective film is formed on the steel surface during intercrystalline corrosion it was necessary to study the action of many solutions such as those listed in table I. Of the various substances that have been found to form this type of film, sodium silicate is most prevalent in boiler operation. It now seems reasonable to believe that practically all intercrystalline cracking, occurring in boilers operating at pressures above 100 pounds, involves the combined action of sodium hydroxide and silicate. Below 100 pounds some oxidizing agents or metallic compounds may be more important than silica in causing cracks.

There is a big gap between the concentrated solutions necessary to produce cracking in the laboratory and the relatively dilute solutions present in operating boilers that have produced intercrystalline cracking. It is usually assumed that the dilute boiler water can evaporate in spaces in riveted seams or tube ends to yield the concentrated solutions that are experimentally necessary to cause failure.

The authors have attempted to study this problem from two viewpoints; considering first, the possible production of intercrystalline cracks in dilute solutions and second, the conditions that may allow

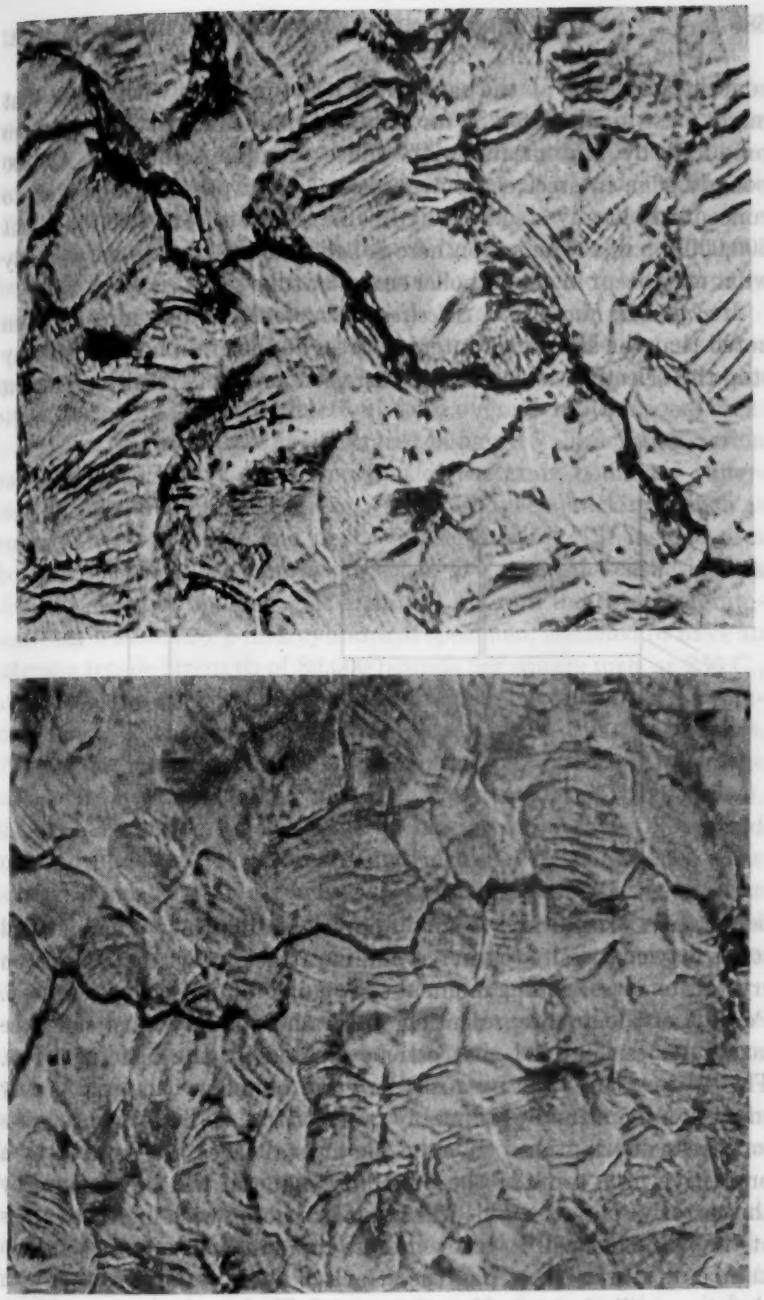

FIG. 4. INTERCRYSTALLINE CRACKS FORMED ON A POLISHED STEEL SURFACE. MAGNIFICATION—500×

Bottom: Sodium hydroxide-lead oxide solution.

Top: Sodium hydroxide-sodium silicate solution.

concentration and at the same time be compatible with those that might exist in a boiler. So far, intercrystalline cracks have not been produced by any means with dilute alkaline solutions. At 200 pounds gage in steel equipment, it has been possible, however, to concentrate locally a sodium hydroxide solution from 2,000 to about 500,000 p.p.m. The action here is believed to simulate very closely what may occur in actual boiler seams or tube seats.

Mechanical Factors in Selective Corrosion. It has already been noted that the absence of internal stress at the grain boundaries may stop the selective attack, if the corrosion products resulting prevent

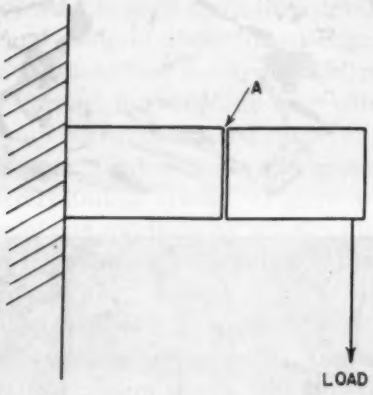

FIG. 5

FIG. 6

penetration of solution to any appreciable depth. What internal stress may contribute to intercrystalline attack is pictured by the two crystals under a bending moment shown diagrammatically in figure 5. Point A of the area representing the grain boundary must suffer the maximum tensile load that can be created by the bending forces. This is especially true because the grain boundary material is very small in amount and presumably quite brittle, so little chance exists for stress distribution. If only the crystal faces are covered by a protective film, some of the boundary material will be removed by the corrosive action. This will result in a notch with increased stress at the base that will favor even more rapid attack. Just as a sharp knife cuts a taut bowstring, the attack of the solution together with the stress will tend to widen the notch, allowing the ingress of fresh corroding solution.

Any further corrosion taking place in the small crevice may create enormous stresses because the reaction products occupy a greater volume than the initial intercrystalline material. These forces could split the grain boundaries further just as a wedge might be driven between two pieces of wood that are glued together. The combined action of selective corrosion, grain boundary stress, and bursting forces exerted by the corrosion products would rapidly propagate the intercrystalline crack.

It will be noted that if uniform corrosion is substituted for selective action there will be no notching and no increase in grain boundary stress except that due to reduction of the overall cross sectional area.

Under a bending stress as illustrated in figure 5 the solution action can take place always on the portion of the grain boundary suffering the maximum tensile stress. This produces cracking which is entirely intercrystalline and never transcrystalline. If instead of a bending load the specimen is subjected to a uniform tensile load, a different situation exists. For example, figure 6 indicates diagrammatically a standard ½-inch cylindrical specimen, assumed to have an ultimate tensile strength of 80,000 pounds per square inch at 250 C., and stressed to 60,000 pounds per square inch in contact with a solution that will produce intercrystalline cracking at this temperature. The solution will start notches at the grain boundaries and when the surface has been penetrated to an average depth of only 0.035 inch, the cross-sectional area will have been so reduced that the applied load will break the remaining sound metal in tension alone. The failure should then be a combination of inter- and trans-crystalline cracking. Actually the intercrystalline cracks are difficult to find because the high stress tends to open them so far that their position with respect to the grain boundaries cannot be determined.

Since boiler metal in service may simultaneously suffer different types of stress it is not surprising to find transcrystalline and intercrystalline cracks at the same time. On the basis of present knowledge, however, if cracked boiler steel shows appreciable intercrystalline attack it must be concluded that the boiler water played a primary part in the damage.

The general assumption that the metal must be under external stress or be carrying an applied load in order to suffer intercrystalline cracking is incorrect. It has been shown repeatedly (6) that specimens may be bent in U shape as shown in figure 1 and crack due to residual stress even though no bolt is used to maintain applied

stress on the specimen. In this case, however, the cracking appears on the inside of the bend because after bending and releasing the applied stress the elastic forces react to produce compression of the outer surface and tension on the inner. Figure 7 shows such cracks as these on the inner surface of a specimen after it has been bent open slightly at the end of the test to make them more apparent. It is clear that residual stresses great enough to promote cracking of the grain boundaries may be left in the steel from cold work.

The failure of these U-bend specimens without applied load demonstrates the improbability that a riveted joint could be so fabricated that it would not fail in contact with a solution that causes intercrystalline attack. The joint could hardly be made without some

FIG. 7

cold-working of the plate and rivet metal which would make the metal susceptible to cracking. Obviously, however, every precaution should be taken during boiler construction to cold-work the steel as little as possible to keep to a minimum the area of metal in which cracking may start. The stress created by the steam pressure, while very important in designing the boiler, is probably of little significance in initiating intercrystalline cracking.

PREVENTION OF INTERCRYSTALLINE CRACKING

Since intercrystalline cracking appears to be a selective corrosion process depending on a certain balance of chemical factors in the solution and stress conditions in the metal, it should be possible to prevent its occurrence in a number of ways. Hypothetically, the steel might be kept free from cold work; practically, this is impossible. A steel immune to intercrystalline attack might be used. However, no low-

cost alloy steel with this property has yet been found. The corroding agent (sodium hydroxide) that attacks the grain boundaries might be eliminated; but operating a boiler without sodium hydroxide in the water may create other dangerous types of corrosion, such as pitting. The partial protective agent that serves to concentrate corrosion at the grain boundaries might be removed. This would mean the almost complete elimination of silica from boiler waters, which is impractical if not impossible at the present time.

Two other alternatives for preventing intercrystalline cracking are much more promising than those already listed. It might be possible through the addition of certain chemicals to the solution to form a continuous rather than partially protective film over the steel, or small openings might be plugged with solid material so there would be no place for the solution to concentrate. This latter is, in effect, accomplished by inside caulking and by the use of welded drums.

Continuous Film Formation. Under certain conditions sodium sulphate produces a mild passivity on steel. This means that a specimen immersed in a sulphate solution develops a surface oxide film that is slightly more resistant to subsequent corrosive action than if the steel had been immersed in water alone. It might therefore be expected that dissolved sodium sulphate would exercise some influence on the intercrystalline corrosion reactions.

A limited effect actually has been observed in accelerated laboratory tests at boiler temperatures, but the protection was destroyed by slight mechanical disruption of the steel surface or by higher concentrations of sodium hydroxide. These laboratory results accordingly, have not given indication that sodium sulphate in solution should be fully effective in preventing intercrystalline failure in an operating boiler.

An attempt has also been made to determine the plugging action sodium sulphate might exert in a small annular opening, but with the apparatus employed it was not possible to exclude the solution and failure occurred. The shape and size of the space in which the solution is concentrated may greatly influence these tests and they are being repeated in an attempt to secure conditions more nearly representative of those in a riveted seam. If sodium sulphate actually does prevent intercrystalline cracking in a boiler, this plugging mechanism seems to be the only one left to explain its action.

The laboratory tests are substantiated to some extent by a case of cracking reported to have occurred in a boiler less than 3 years

old, operating at 100 lb. pressure. Severe intercrystalline cracking resulted in spite of the reported maintenance of about twice as much sodium sulphate as was required according to the A.S.M.E. ratio.

Certain oxidizing agents have been found which, under the conditions presented by the laboratory apparatus, are materially better than sodium sulphate in preventing failure. These materials react directly with the steel and it is not surprising that they stop cracking. They might be useful in boiler operation if more information were available concerning their possible effect in general, overall-surface corrosion.

In acid pickling of steel it has been found that certain organic inhibiting agents may be added to the bath to reduce the attack when the solution has dissolved the mill scale and reached the metal surface. It is believed protection of the metal in these cases results from a firmly bonded impenetrable film of organic material that covers the steel surface. If such a film could be secured in a hot alkaline solution it should prevent intercrystalline cracking.

Several of the inhibiting agents used in pickling baths have been tried in the tests for intercrystalline cracking, but they have not prevented failure. Many of them are not sufficiently stable at elevated temperatures to be useful in boiler operation. The first series of organic materials that was found to prevent intercrystalline cracking were those containing lignin. Their powerful inhibiting action contrasts sharply with the comparatively weak effect of sodium sulphate. For example they will stop cracking in any caustic concentration whatsoever and if the protective film is deliberately destroyed by mechanical action it reforms so quickly that no intercrystalline attack is allowed even to start.

Quebracho and cutch at some temperatures and concentrations are almost as effective in protecting the steel as the lignin compounds. Oak tannins, chestnut extract, and tannic acid (U.S.P.) were found to be much less effective inhibitors. A more detailed discussion of the effect of various organic materials will be found in an earlier paper (7).

Oxidation of the steel surface by the lignin compounds, quebracho and cutch may produce the beneficial action, but comparison with sodium sulphite, which has been found to act as an oxidizing agent with respect to steel at boiler temperature (8), does not indicate that this is true. The authors are rather inclined to believe that the protection is afforded by a film of organic material covering the steel surface.

CONCLUSIONS

This investigation has attempted to determine how intercrystalline cracks occur, whether the use of sodium sulphate will offer adequate protection, and what means other than sodium sulphate can be used to protect the steel.

To produce the cracking, the solution, (usually sodium hydroxide-sodium silicate), deposits a partially protective film over the crystal faces of the metal, leaving the grain boundaries relatively unprotected. These grain boundaries are attacked by the corroding action of the sodium hydroxide to form a notch in the metal. If they are under internal stress from cold work, or under external applied stress, the notch widens and the entrance of fresh solution causes further penetration into the metal. When the notch is deep enough the corrosion products exert bursting forces because they occupy more volume than the initial intercrystalline material. This action is analogous to the bursting forces produced by the expansion of water as it freezes in a deep crack in a stone.

This work definitely shows that external applied stress is not necessary to the production of cracks. Deformation of the steel such as is produced by driving a rivet, or rolling in tube ends may result in sufficient residual stress in the metal to make possible intercrystalline cracking by concentrated sodium hydroxide-sodium silicate solutions. It has also been shown that this type of failure cannot be produced in boiler metal by stress alone, by hydrogen, or by corrosion fatigue.

The laboratory experiments showed that lignin and some other organic materials offered much more protection from cracking than did sodium sulphate. They have been used successfully at pressures up to 550 pounds and in concentrations of from 10 to 20 per cent of the concentration of sodium hydroxide present. A method of analysis is available for their determination. Many lignin containing compounds are waste products and it is important that they be free from known undesirable impurities of which certain sugars are typical. Moreover, they have not been found to offer protection above 550 pounds pressure because of decomposition.

The laboratory work essentially has achieved the initial objectives, but certain questions still remain to be answered. It is desirable to extend this investigation to the use of lignin compounds into actual boiler operation. Whereas the investigation has thus far considered these from the standpoint of their effect on intercrystalline cracking, it is important that they be examined for possible decomposition and scale formation, as well as for their effect on foaming and priming

when used as a part of the treatment of boiler water. This will furnish the engineer with basic information so he may feel secure that their introduction into the water will not create difficulties. Until this work is completed no attempt should be made toward the direct application of these results. Some tests in this direction are now going forward and more would be desirable.

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ABSTRACTS OF WATER WORKS LITERATURE

Key. 29: 408 (Mar. '37) indicates volume 29, page 408, issue dated March 1937. If the publication is paged by issues, 29: 3: 408 (Mar. '37) indicates volume 29, number 3, page 408. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; W. P. R.—Water Pollution Research (British).*

WATER WORKS ABROAD

Water Supply and Sanitary Engineering in 1937. ANON. The Engr. (Br.) 165: 57 and 73 (Jan. 14 and Jan. 21, '38). During '37 more work was carried on or started in England than in preceding years when authorities were financially handicapped. For London, water works now in progress include the Chingford No. 2 reservoir, reconstruction of high-level, slow sand filters at Surbiton, reconstruction of filters at Kempton Park, and 17 mi. of 42″ pipe from Hampton to Honour Oak. Contract has been let for the construction of a 4.4 billion gal. (Imp.) reservoir in the Thames Valley at Staines. Among the larger water improvements in the provinces have been: at Birmingham continued work on the extension of Northfield reservoir; at Frankley the construction of a 4 m.g.d. (Imp.) filter plant; progress has been made on the construction of dam for the Ladybower reservoir. This is an earth embankment 1,250′ long and 143′ high, to impound 5.5 billion gal. (Imp.). The project included the laying of 6.5 mi. of 39″ pipe; at Edinburg two slow sand filters with total capacity of 3 m.g.d. (Imp.) were added; at Liverpool 3.6 mi. of pipe were laid on the Vyrnwy aqueduct; at Manchester steady progress has been made on the Haweswater dam; at Newcastle and Gateshead the rapid sand filter plant was increased by 3 m.g.d. (Imp.); at S. Essex considerable progress was made on the construction of the Abberton storage reservoir; at W. Cheshire the Mouldsworth water supply to the Wirral Peninsula was inaugurated in Oct. At Paris, France works undertaken are mainly in connection with scheme for bringing water from aqueous sands of the Vals de Loire. At Cannes work has been started on dam across the Alpine River which will impound 135 mil. cu.m. Other minor work in the French Provinces is described. At Rangoon in Burma an earth dam 136′ high will form the Pegu Yomas Reservoir to store 2,370 million cu.ft. —*H. E. Babbitt.*

Municipal Engineering in 1937. Water Supply. ANON. Surveyor (Br.) 93: 117 (Jan. 28, '38). During the last 150 yrs. works for water supply have gone forward with increasing rapidity. The increased demand for water is due to the requirements of various trades, increased population and building developments, and to altered living conditions. Knowledge of national water resources is increased through work of the national hydrographic survey and

cooperation therewith by those engaged in work on river control and land drainage. The pollution of rivers hitherto has not been due to lack of proper legislation but to lack of its enforcement. One result of the visit of a committee of the Trades Union Congress to the Minister of Health has been more attention to rural water supplies. The British Water Works Association has devoted special attention to the matter of water pollution, particularly in connection with the pollution of stored water and the better protection of water supplies. American methods of water treatment and of corrosion prevention have attracted attention in England and are well worthy of study by English water works operators. Interesting work has been reported with regard to the subject of sinking of wells in fine sand formations. The London water demand amounted to 398.8 m.g.d. (Imp.) during the past year. The increased demand indicates possibility that sources of supply for the city may prove insufficient for the future. Dam building is probably reaching a climax as indicated by the tremendous structures under construction. Progress in water pumping has been in the direction of greater economy in operation, and resourcefulness has been shown in the protection of equipment against floods. Political difficulties in India are handicapping water works progress there. In distribution systems attention has been paid to expansion joints and to the prevention of leakage and waste, with special emphasis on the maintenance of water meters. Among the new works of importance may be included the reservoir in the Mardale Valley in Westmorland and the Haweswater scheme; the Shing Mun dam near Hong Kong; the reservoir works in the Lea Valley; and the opening of the Burnhope reservoir of the Durham County project.—*H. E. Babbitt.*

Problems with Water Supplies in the Netherlands. W. F. J. M. Krul. Gas-u. Wasser 80: 822 (Nov. 13, '37). Holland is a man-made country. A large section of it lies below sea level and another large section is exposed to floods from the rivers Rhine and Meuse. Since ancient times engineering has been highly developed to protect and drain the land. Malaria and typhoid fever were formerly prevalent, but these diseases have been overcome and the Netherlands is now one of the most healthful countries. With three-fourths of the 8½ million population living in the low western part, difficulties arise in obtaining sufficient suitable water. Surface waters can only be used to a limited extent, as the flatness of the country does not allow the construction of storage reservoirs and as the rivers are highly polluted and in their lower ranges subject to salting by sea water. Rotterdam (pop. 600,000) receives its water from the Meuse. The water is settled for 12 to 20 hrs., filtered through rapid sand filters, treated with activated carbon, then passed through slow sand filters and chlorinated. About 35 to 40% of the Amsterdam (pop. 800,000) water is also secured from a surface supply. Only a few other communities in the east and south sections have surface supplies. Ground water comes in general from two types of soil, in the eastern part from Pleistocene sands and along the coast from the base of the dunes. In the low lying Polderland back of the dunes heavy clay deposits 50′ to 60′ thick allow the obtaining of water only occasionally from imbedded sand layers, the water below the clay being brackish. Pumping of fresh water into the ground has been tried, but caused

a raising of the clay soil and also clogging of the sand. In the dunes the water is obtained from shallow wells, and, where larger quantities are required, from infiltration galleries or even from open ditches dug below the ground water level. Withdrawal of water from the dunes must be done carefully, as a large lowering of the water table will cause an inflow of salt water and will also damage the agricultural use of the land. Under such conditions it can be easily understood that the State does much for the study of water resources and for the reduction of river pollution. Several government bureaus and commissions are coperating. In the pollution problem of the Rhine a closer cooperation with neighboring countries is desired. On Jan. 1, '36 water supplies were available in 720 of the 1064 communities, or about 82% of the population. Of the 144 mil. gal. used daily in the Netherlands, 27% are from surface waters, 29% from water in the dunes, and 44% ground water outside the dunes. It is probable that in the future surface water will have to be used more extensively. —*Max Suter.*

On the Treatment of Drinking Water with Ozone. N. SCHONFELDT. Gas- u. Wasser 80: 130 (Feb. 27, '37). Tests were made in '36 in two of Stockholm's waterworks to improve color, taste and odor by the use of ozone. At the Norsborg plant the effluent of slow sand filters was treated with 2.6 grams of ozone per cu. meter. Reported that the color was reduced from 25 mg. platinum per liter to 8 mg. and changed from yellow brown to blue green. Inasmuch as the German color standards are practically identical with our American standards (German standard: 2.49 grams K_2PtCl_6, and 2.02 grams $CoCl_26H_2O$ in 200 ml. concentrated HCl, diluted to 1 liter for color of 1000 mg. Pt per liter) we can take practically the above data as a reduction in color from 25 to 8 p.p.m. At the Lovön plant the effluent of rapid sand filters was treated with 1.3 to 1.8 grams ozone per cu. meter. Of this amount 1.0 to 1.4 grams were consumed. Taste and odor improved as much as if the water had been treated with activated carbon. When the water was filtered more slowly the effect of the ozone was more marked. The improved quality of the water was maintained on standing for 24 hrs. The slowing down of the flow through the filters caused a reduction of the dissolved oxygen content of the water and this may indicate a biological action that may explain the favorable results. The article does not show how the amount of ozone was determined but as German chemists worked there they may have used the German standard method. This is as follows: In a 200 ml. sample of the water use 5 ml. of a 10% potassium iodide solution, 1 ml. of a 1% starch solution and titrate without acidification with a $N/100$ thiosulfate solution. One ml. of the thiosulfate solution used represents 1.2 p.p.m. ozone.—*Max Suter.*

Problems of the Water Supply in the Industrial District of the Rhine and Westfahlen. GOTTFRIED FLACH. Gas- u. Wasser 80: 918 (Dec. 25, '37). This district comprises a territory about 72 mi. E-W and 37 mi. N-S. It has mainly coal and iron industries, a population of about 6,000,000 and water consumption of 277 to 317 m.g.d., of which about 2/3 are used by the industries. Although five rivers, the Ruhr, Emscher, Lippe, Wupper and the Rhine flow through this district, a dependable water supply is only obtained from the

Ruhr and a little from the Rhine. The Emscher is heavily polluted with sewage, the Lippe carries salty mine-waters and the Wupper is polluted by the textile industries. In order that the Ruhr can furnish the great amount of water, about one-half of which is never returned to it but is diverted into the other rivers, many dams and storage reservoirs had to be built. At present there are twelve dams, eight of which are connected with power plants producing a total of 28,000 hp. The quality of water is maintained by extensive treatment of the inflowing sewage, domestic as well as industrial, by the aid of the reservoirs in promoting natural purification of the river water and by always extracting the water as ground water, often after artificial enrichment and short natural filtration.—*Max Suter.*

Hygienic Aspects of Private Water Supplies Within the City of Düsseldorf. ALFONS KAESS. Gesundheits-Ingenieur (Ger.) **61**: 66. (Jan. 29, '37.) Düsseldorf is on the bank of the Rhine and is built on tight clay six to ten feet thick. Underneath are water-bearing sands and gravels to a depth of 60′ to 100′. The natural ground water level is inclined towards the river and varies to a greater or less extent with the river stages, depending upon the distance from the river. At a distance of about 2 miles from the river the high and low levels appear in the ground water about 12 weeks after those in the river and the variations are about one-half of those in the river. The ready availability of ground water results in the existence of about 285 private water supplies besides the public supply. Many of the private wells are of unsatisfactory construction, are inaccessible for inspection and are operated by untrained help. The results of the chemical and bacteriological tests on 81 private wells are given. It is shown that many of these wells are sunk in zones where organic pollution of the ground water exists. From the coli test alone 65% of the supplies have to be condemned. Means should therefore be available to force connection to the city supply especially in cases of hotels and meat plants. Chlorination of private supplies is not recommended, as the necessary supervision would be lacking.—*Max Suter.*

Standardization of Water Meters. (In German.) H. SCHELLENBERG. Monatsbulletin (Swiss) **17**: 272 (Nov. '37). Efforts have constantly been made to improve water meters from the standpoint of longer life, greater accuracy and adaptability. This has led to a large number of meter types and changes in the models made by each manufacturer making repair difficult and costly. The particular desirability of standardizing parts requiring replacement during repair is discussed. Water dept. of Zurich has set up a series of specifications which it believes will be an aid to standardization. **Specifications for Water Meters of the Water Dept. of Zurich.** H. Schellenberg. Ibid. **17**: 295 (Dec. '37). Specifications for meter parts are given in considerable detail with drawings, tables of delivery and pressure losses, etc. Materials to be used are red brass, nickel and hard rubber; agate bearings are being replaced by sapphire. It is hoped adoption and publication of these standards will lead to more general use in Switzerland.—*Martin E. Flentje.* Editor's Note.—The article above abstracted is a lengthy one, and of considerable

interest. Its details, many of which are presented in illustrative or tabular form, are of such extent as to make it impractical to do them justice in an abstract.

The Shanghai Waterworks Co., Ltd.: Annual Report of Engineer and Manager for '36. C. D. PEARSON. Exceptionally complete operating data, tabular and graphical, are given and discussed, including detailed analyses of consumption, purification and pumping plant operation, etc. Av. consumption was approx. 44 m.g.d. and max. somewhat over 58 m.g.d., ratio being 1:1.33. Ratio of av. hourly demand to max. hourly demand was 1:1.86. The daily per capita consumption for domestic purposes averaged 20.37 gal. The supply is 100% metered and unaccounted for water amounted to 16.84%. Mud removed from settling tanks totaled 8,197 tons. Av. alum dosage was 0.951 g.p.g. and turbidity of untreated Whangpoo R. and of settled water averaged 133.2 and 23.1 p.p.m., respectively. The slow sand plant delivered 32% of total water supplied and the rapid sand plant 68%. Av. no. of days' service between cleanings of slow sand filters was 17.4 and av. rate of filtration 1.61 gal. per sq. ft. per hr. Av. rate of filtration through rapid sand filters was 100 gal. per sq. ft. per hr. and wash water used averaged 2.73% of water filtered. All water applied to rapid sand filters is prechlorinated, av. dosage during yr. being 0.985 p.p.m. Av. chlorine dosages at the other 2 points in the purification process, the rapid sand filters and the main engines, were 0.403 and 0.287 p.p.m., respectively. Superchlorination was not required and the sulfur dioxide dechlorination equipment was therefore not in operation during the year. Of 1802 samples of delivered water examined for coliform bacteria, 95.7% were negative in 100 cc., 3.6% positive in 100 cc., 0.5% in 10 cc., and 0.1% in 1 cc. Complaints received totaled 118, or 11 per million consumers, 50% of which were due to turbid water, 14% to taste and 32% to presence of living organisms in the water. Latter were largely small red worms, the larvae of the aquatic fly, *Diptera Chironomus*, a reservoir having become infected during a period of inoperation. Cost of pumping per mil. foot gal. and per mil. gal., respectively, were as follows: primary pumps (river to settling tanks) 12.27¢ and $3.01; secondary pumps (settling tanks to filters) 20.45¢ and $6.08; main pumps (filters to distr. system) 12.91¢ and $15.90. Pumps are driven by steam, electricity, gas and Diesel engines. Operating data for individual pumps are given. Considerable saving was effected in cost of lubricating oil by use of filtered oil, viscosity being maintained by addition of a priming oil. Cost of steam was $1.1498 per 1000 lb. and B.t.u. consumed per lb. of steam 2,102. The no. of meters in use at the end of the yr. was 19,350. Av. repair cost per meter was $5.44; 1,949 meters were repaired and reconditioned and 2,763 were overhauled. Under distribution, details are given regarding extensions and maintenance of mains, services, hydrants and valves. Hydrants maintained during yr. totaled 2,323, av. cost of maintenance being $11.95. No. of leaks per mi. of mains averaged 4.84, total of 933 being repaired. Water derived from subterranean sources by private property owners amounts to approx. 20% of that supplied by company. Gross revenue from sale of water during yr. was $5,116,941, an av. of $0.389 per 1000 gal. Only 1.8% of the services had to be shut off for non-payment of bills.—*R. E. Thompson.*

Ruhr and a little from the Rhine. The Emscher is heavily polluted with sewage, the Lippe carries salty mine-waters and the Wupper is polluted by the textile industries. In order that the Ruhr can furnish the great amount of water, about one-half of which is never returned to it but is diverted into the other rivers, many dams and storage reservoirs had to be built. At present there are twelve dams, eight of which are connected with power plants producing a total of 28,000 hp. The quality of water is maintained by extensive treatment of the inflowing sewage, domestic as well as industrial, by the aid of the reservoirs in promoting natural purification of the river water and by always extracting the water as ground water, often after artificial enrichment and short natural filtration.—*Max Suter.*

Hygienic Aspects of Private Water Supplies Within the City of Düsseldorf. Alfons Kaess. Gesundheits-Ingenieur (Ger.) **61**: 66. (Jan. 29, '37.) Düsseldorf is on the bank of the Rhine and is built on tight clay six to ten feet thick. Underneath are water-bearing sands and gravels to a depth of 60′ to 100′. The natural ground water level is inclined towards the river and varies to a greater or less extent with the river stages, depending upon the distance from the river. At a distance of about 2 miles from the river the high and low levels appear in the ground water about 12 weeks after those in the river and the variations are about one-half of those in the river. The ready availability of ground water results in the existence of about 285 private water supplies besides the public supply. Many of the private wells are of unsatisfactory construction, are inaccessible for inspection and are operated by untrained help. The results of the chemical and bacteriological tests on 81 private wells are given. It is shown that many of these wells are sunk in zones where organic pollution of the ground water exists. From the coli test alone 65% of the supplies have to be condemned. Means should therefore be available to force connection to the city supply especially in cases of hotels and meat plants. Chlorination of private supplies is not recommended, as the necessary supervision would be lacking.—*Max Suter.*

Standardization of Water Meters. (In German.) H. Schellenberg. Monatsbulletin (Swiss) **17**: 272 (Nov. '37). Efforts have constantly been made to improve water meters from the standpoint of longer life, greater accuracy and adaptability. This has led to a large number of meter types and changes in the models made by each manufacturer making repair difficult and costly. The particular desirability of standardizing parts requiring replacement during repair is discussed. Water dept. of Zurich has set up a series of specifications which it believes will be an aid to standardization. **Specifications for Water Meters of the Water Dept. of Zurich.** H. Schellenberg. Ibid. **17**: 295 (Dec. '37). Specifications for meter parts are given in considerable detail with drawings, tables of delivery and pressure losses, etc. Materials to be used are red brass, nickel and hard rubber; agate bearings are being replaced by sapphire. It is hoped adoption and publication of these standards will lead to more general use in Switzerland.—*Martin E. Flentje.* Editor's Note.—The article above abstracted is a lengthy one, and of considerable

interest. Its details, many of which are presented in illustrative or tabular form, are of such extent as to make it impractical to do them justice in an abstract.

The Shanghai Waterworks Co., Ltd.: Annual Report of Engineer and Manager for '36. C. D. PEARSON. Exceptionally complete operating data, tabular and graphical, are given and discussed, including detailed analyses of consumption, purification and pumping plant operation, etc. Av. consumption was approx. 44 m.g.d. and max. somewhat over 58 m.g.d., ratio being 1:1.33. Ratio of av. hourly demand to max. hourly demand was 1:1.86. The daily per capita consumption for domestic purposes averaged 20.37 gal. The supply is 100% metered and unaccounted for water amounted to 16.84%. Mud removed from settling tanks totaled 8,197 tons. Av. alum dosage was 0.951 g.p.g. and turbidity of untreated Whangpoo R. and of settled water averaged 133.2 and 23.1 p.p.m., respectively. The slow sand plant delivered 32% of total water supplied and the rapid sand plant 68%. Av. no. of days' service between cleanings of slow sand filters was 17.4 and av. rate of filtration 1.61 gal. per sq. ft. per hr. Av. rate of filtration through rapid sand filters was 100 gal. per sq. ft. per hr. and wash water used averaged 2.73% of water filtered. All water applied to rapid sand filters is prechlorinated, av. dosage during yr. being 0.985 p.p.m. Av. chlorine dosages at the other 2 points in the purification process, the rapid sand filters and the main engines, were 0.403 and 0.287 p.p.m., respectively. Superchlorination was not required and the sulfur dioxide dechlorination equipment was therefore not in operation during the year. Of 1802 samples of delivered water examined for coliform bacteria, 95.7% were negative in 100 cc., 3.6% positive in 100 cc., 0.5% in 10 cc., and 0.1% in 1 cc. Complaints received totaled 118, or 11 per million consumers, 50% of which were due to turbid water, 14% to taste and 32% to presence of living organisms in the water. Latter were largely small red worms, the larvae of the aquatic fly, *Diptera Chironomus*, a reservoir having become infected during a period of inoperation. Cost of pumping per mil. foot gal. and per mil. gal., respectively, were as follows: primary pumps (river to settling tanks) 12.27¢ and $3.01; secondary pumps (settling tanks to filters) 20.45¢ and $6.08; main pumps (filters to distr. system) 12.91¢ and $15.90. Pumps are driven by steam, electricity, gas and Diesel engines. Operating data for individual pumps are given. Considerable saving was effected in cost of lubricating oil by use of filtered oil, viscosity being maintained by addition of a priming oil. Cost of steam was $1.1498 per 1000 lb. and B.t.u. consumed per lb. of steam 2,102. The no. of meters in use at the end of the yr. was 19,350. Av. repair cost per meter was $5.44; 1,949 meters were repaired and reconditioned and 2,763 were overhauled. Under distribution, details are given regarding extensions and maintenance of mains, services, hydrants and valves. Hydrants maintained during yr. totaled 2,323, av. cost of maintenance being $11.95. No. of leaks per mi. of mains averaged 4.84, total of 933 being repaired. Water derived from subterranean sources by private property owners amounts to approx. 20% of that supplied by company. Gross revenue from sale of water during yr. was $5,116,941, an av. of $0.389 per 1000 gal. Only 1.8% of the services had to be shut off for non-payment of bills.—*R. E. Thompson.*

Prevalence of Typhoid Fever in the City of Manila. E. HERNANDO AND A. ALOMIA. Bul. of Hygiene (Br.) 13: 105 (Feb. '38). Orig. abstr. from Bul. Manila Bur. of Health, 17: 79 ('37). Data on typhoid prevalence '10 to '34 are given, correlated with changes in the city water supply and sewerage systems. Incidental data on the water system: In '05 part of water supply was from Montalban R., part from an artesian well. In '12 another well drilled; by '18, 42 wells in use. Many of these wells were found to be structurally defective and 21 were closed. The city water (that derived from the river) was freely supplied; in '21 there were 278 public taps. In '22, of 1,141 samples from these, 193 were positive for coliform organisms. In '28 automatic chlorinators installed on new reservoir for river water. Since '29 Montalban R. used only occasionally.—*P. S. Wilson.*

Mexico City to Improve Its Water System. ANON. Eng. News-Rec. 120: 45 (Jan. 13, '38). The municipal government of Mexico City plans expenditure of approx. $8,300,000 to provide additional water for Mexico City and the federal district. Existing system was designed for population of about 500,000, whereas federal district now has a population of approx. 1,500,000. Planned to add about 100,000 g.p.m. to city's supply by impounding and bringing in water from various streams in Lerma lagoon district, increasing supply to about 150,000 g.p.m. Water will be brought to city through an aqueduct which will include an open channel, an 81½-mi. tunnel and a covered channel. Power to the extent of approx. 15,000 hp. will be generated at 3 points on the aqueduct and a portion of it used for pumping water.—*R. E. Thompson.*

WATER WORKS—DOMESTIC

St. Louis, Mo., Annual Report of Water Commission for Year Ending Apr. 12, '37. Report of Water Comm. John B. Dean, Water Commr., to Edward E. Wall, Dir. Pub. Util. Pop. (U. S. Census est.) is 860,000, by '36 census 851,879. Income for yr. totaled $3,755,406 of which $1,920,445 came from flat rate consumers, $1,812,076 from meter rates, and remainder from sources marked miscellaneous. Net increase of all water rates amounted to 5.56% over previous yr. Net operating and maintenance cost of water works amounted to $1,909,479, a reduction of $102,678. Current operating and maintenance expenses including bond retirement funds and interest on bonds outstanding amounted to $3,311,646 net, $443,760 less than rec'd. from water sales and misc. sources. Cost of water works to date equals $51,642,729. Total water cons. for yr. was 46,429.876 mil. gal., av.—127.205 m.g.d., max.—201.146 m.g.d., min.—87.837 m.g.d., and av. per cap. cons. per day—148 gal. Cost of pumping given as: (per mil. gal. pumped for pumping station expenses alone) (a) into settling basins, Chain of Rocks—$4.263; (b) in sed. basins Howard Bend —$2.431; (c) into mains at Baden—$14.929; (d) into mains at Bissell's Point —$7.000 (e) into res. at Stacy Park—$6.517. Distr. sys. contains 1,238.10 mi. of c.i. and steel pipe, 3″ to 62″. Steel mains, 24.27 mi. or 1.97% of total; 3″ and 4″ in service, 16.12 mi. Total number of fire hydrants in service (public and private) is 14,954; no. of valves is 18,966, with 465 installed during yr. Range of pressure on dist. mains is from 20 to 125 lbs. Lead, c.i., and copper services in use; total services, 151,887, with 14,611 meters in service, equaling

9.62% of all services. Receipts from metered services is 48.54% of total revenue, an increase of 13.10%. Supply taken from Miss. and Mo. Rivers into 2 purification plants, Chain of Rocks on Miss. and Howard Bend on Mo.; with rated cap. of 160 and 80 m.g.d. respectively. Water softened with lime, coagulated, filtered and sterilized. Chemicals used are lime, iron sulfate, alum, ammonium sulfate, CO_2 gas, and chlorine. Total cost of purification was $408,013, av. of $8,788 per mil. gal., decrease of $0.112. Turbidity of tap water av'd. 0.16 p.p.m. for yr., av. bacterial count on agar was 7 per ml. and *Esch. Coli* index was 0.01 per 100 ml., max. color was 21, min.-4 and av.-8, av. hardness was 100, a reduction of 66 from that of river. Av. reduction in hardness was 14.3 p.p.m. per grain of lime added. Temp. of water at Chain of Rocks station varied from min. of 38 to max. of 88 with av. of 61, at Howard Bend plant from 38 min. to 91 max. with 62 av. for yr. Total of 10,683 bacterial tests were made and 18,605 chem. tests. 6 deaths in city due to typhoid during '35, 7 in '36; based on pop. of 851,789 death rate per 100,000 was 0.82. Considerable detail is given in narrative and tabular form in report of individual plants and operating divisions, together with several graphs and illustrations.—*Martin E. Flentje.*

Pasadena, Calif., Water Dept. Annual Report for Year Ending June 30, '37. Chief Engr. Gen'l. Mgr. MORRIS S. JONES to City Mgr. C. W. KOINER. Since last report new concrete warehouse and shop completed and occupied, pumping system changed to operate under 60-cycle frequency, 2 small water companies purchased and more new mains and services laid than in any previous yr. Operating revenue increased 0.5% to $870,047. Non-operating revenue increased from $34,337 to $70,237, total gross revenue being $940,501. Operating and maintenance expense, including depreciation and bond interest and redemption, increased 15.6% to $856,059. Net profit decreased from $125,594 to $14,204. Cost of water sold per 100 cu.ft. totaled 15.51 cents; among costs were following; source water supply 0.68¢ (per 100 cu. ft.)—4.28% of water revenue; pumping expense 1.4¢—6.62%; purification expense 0.15¢—0.96%; distribution expense 0.78¢—4.98%; commercial expense 0.92¢—5.83%, general expense 2.73¢—17.28%, depreciation and interest on bonds 9.21¢—58.44%. Total water produced 607,304,200 cu. ft. of which 360,019,400 pumped (39.3%); total sold was 551,805,700 cu. ft. Consumption per capita per day av. 117.2 gal. compared with 121.5 gal. for yr. '35-'36; av. daily consumption for yr. was 11.31 mil. gal. Rainfall for yr. was 28.81″, 142% of 55 yr. normal of 20.12″. Mean yearly temp. was 63.1°—slightly over the 29 yr. mean of 62.0°. Number of active services increased 1,031 (3.9%) to 27,197. Dist. system contained (June 30, '37) 1,845,190′ of mains (349.5 mi.), of which approx. 74.7% is c.i. Entire system of transmission, supply and pump mains equals 375.7 mi. Min. pressure except in small areas is not lower than 30 lbs. Cost of pumping from deepwell plants with av. lift of 321′ was $0.1278 per 1000 cu. ft. and $0.0398 per 1000 cu. ft. per 100′ lift for operation and maintenance. Total cost (for same units) of $0.0677 per 1000 cu. ft. per 100′ lift. Booster plant costs were $0.0413 per 1000 cu. ft. and $0.0510 per 1000 cu. ft. per 100′ lift and total of $0.0896. 1513 fire hydrants are in service in Pasadena, 145 in county fire protection district, and 24 in San Marino. System has total of 3799 gate valves

and 974 flush tanks. Meters totalled 27,109, number of each of 11 makes in use tabulated. Alk. of water varies from 96 to 203 p.p.m., total hardness 85 to 218 p.p.m., pH 7.56 to 8.32; normal hardness of mixed sources averages 147 p.p.m. (8.6 g.p.g.). Map showing location of pumping plants, res.'s and prin. dist. mains; graphs by mo. water production from 1914–15 to present and of daily water consumption for yr. and several photographic illustrations are included.—*Martin E. Flentje.*

Air Conditioning Increases Demand on the Phoenix (Ariz.) Water Supply System. JAMES GIRAND. W. Cons. News. 12: 381 (Oct. '37). Natural growth of population accounts for 1.5 m.g.d. increase in water consumption over previous summer and air conditioning another 1.5 m.g.d. bringing daily av. use of water in Phoenix in summer to 17.5 m.g.d. Pop. now 75,000 growth, expected within 10 yrs. to 125,000. Air conditioning of large bldgs. of no importance because of ease of obtaining well water 30′ from surface. Domestic air conditioning units of 3 types: (1) refrigeration, (2) radiator, (3) evaporative. Practically all 160 domestic refrigeration type units in city cooled with water from city system, water req'd. approx. 5 g.p.m. per unit. Operated about 14 hrs. per day producing desirable water load. Radiator type uses cool water circulated through radiators of automobile type in which air can be cooled to within one degree of water temp. No moisture added to air an advantage, small units cap. about 1000 cu. ft. per min. of air, require from 2 to 6 g.p.m. of water. Number in use in Phoenix 200, few hooked on to water system. Evaporation type has most widespread use, in some sections 90% of homes so equipped, estimated 6,000 in service out of some 12,000 domestic consumers. Consists of large cap. air fan or blower drawing air through pads of excelsior kept wet by small drip or spray of water. Typical blower will have cap. of 4,000 cu. ft. per min. and area of excelsior pads will be about 40 sq. ft. Requires thorough ventilation of house to avoid unbearable humidity. Interesting data from more complete comparative table given gives following figures for (1) refrigeration, (2) radiator, (3) evaporation type of unit respectively: Temp. inlet air dry bulb, (1) 80°, (2) 95°, (3) 95°; Outlet temp. dry bulb, (1) 60°, (2) 75°, (3) 75°; relative humidity outlet air (1) 70% (2) 66%, (3) 90%; volume (cu. ft. per min.) of air (1) 1400, (2) 1000, (3) 4000; water rate g.p.m. (1) 5, (2) 2, (3) 0.25; power requirements hp., (1) 3, (2) 0.25, (3) 0.33; approx. monthly cost (1) $45, (2) $16.70 (3) $7.50. Reasons are given for continuance in Phoenix of flat rate charges.—*Martin E. Flentje.*

Winter and the Waterworks. W. W. DEBERARD. Eng. News-Rec. 120: 103 (Jan. 20, '38). Cold weather precautions observed in Eau Claire, Wis. are reviewed, together with other interesting details of plant operation. Population of the city is 32,000. During winter, all of the 730 hydrants are tested for leakage every week. If leakage is found which may cause trouble because of freezing, about a gal. of alcohol is introduced. During the extreme weather of 2 yrs. ago, in spite of precautions, 65 hydrant branches froze: thawing was effected with 2 trucks equipped with steam boilers. For thawing hydrants, a 2½″ steam jet under 75–80-lb. pressure was pushed down outside the barrel. There are now 647 valves in the system, some 275 having been cut in with an

inserting machine since supply was acquired by city in '09. The valves require very little maintenance other than the yearly inspection, when all defects are remedied. Av. length of main a single break would put out of service is 810′ in business district (Original article stated 80′ in error.—Ed.) and 1,260′ in residential area. Services are laid and maintained by licensed and bonded plumbers, cover being 7′. Early installations were mostly wrought iron and lead, but recently copper has become quite popular. Meter testing equipment consists of a 3-cu. ft. vertical tank with a gage graduated in percentages above and below the even ft. marks. Permissible tolerance is 2% either way. In service, meters slow down due to corrosion. About 10% of the 6,000 meters are in the shop for test and repair each yr. Most of the 750 meters installed 28 yrs. ago are still in service: 40 yrs. is considered the life expectancy of a good meter. A system of meter history cards has been adopted. Three yrs. ago, excessive contents of iron and manganese led to development of new well field. Two wells have been added to the 4 installed at that time. The water is practically free of iron but contains algae, protozoa and other growths, necessitating chlorination. Ammonia is also employed. The pumping station was put out of commission in '37 by a fire, the burning roof falling on equipment and destroying the insulation. Station was being reconstructed at the time to reduce fire hazard. Fire spread from falsework to temporary wooden roof. Service was restored some 15 hr. after fire. Industrial plants were cut off and householders requested to ration themselves. This enabled the 3.5 mil. gal. reservoir to maintain service during shutdown.—*R. E. Thompson.*

Waterworks Operation at Des Moines. W. W. DeBerard. Eng. News-Rec. 120: 265 (Feb. 17, '38). The water works have been under municipal control for 18 yrs. Pumping station is located in one of finest parks of city and has enviable national reputation for attractiveness. Supply drawn from galleries in the flat broad Racoon R. Valley, overlying areas being flooded 6 mo. of yr. by pumping from river and from 2 billion-gal. Kildeer Reservoir. Services are 99.5% metered. All domestic meters are overhauled at least every 2 yrs. and sizes over 2″ receive attention every yr. Usual tolerance of 2% variation on large flows is adhered to in adjusting meters: 5% variation is considered satisfactory for 1/16″ stream and meter must register on a 1/32″ stream. About 99% of the meters are brought in for test on complaint or because meter readers find them slow. Per capita consumption averaged 98.6 gal. in '36, equivalent to 40,700 gal. per mi. of pipe. Population served is 150,000: in '36 there were 33,358 services. The quantity of water billed through meters is 68.8% of that pumped: municipal uses are not metered. Detailed meter records are maintained. Hydrants are inspected once each yr. and intensively in winter. Samples collected daily from 6 points for bacteriological examination: tests for coliform bacteria are negative and in '36 the av. bacterial count at 37°C. was 0.403 per cc. The supply is chlorinated. Chemical analyses show the following results, in p.p.m.: total solids 425, bicarbonates 299, sulfates 106, free carbon dioxide 17.5. The pH value is 7.13 and total hardness ranges from 12 to 22 g.p.g. Book value of plant has increased from $3,480,000 when purchased in '19 to $8,350,000. Deducting de-

preciation, fixed assets as of Dec. 31, '36 were $6,650,000. Bonded indebtedness of $4,878,000 is being amortized by sinking fund derived from earnings.—*R. E. Thompson.*

A $1,623,000 Plan for Bellingham (Wash.) Water Supply. ANON. W. Cons. News, 13: 10 (Jan. '38). Eventual 100 m.g.d., present 30 m.g.d. cap. industrial and domestic water supply for Bellingham to be started in '38. Estimated cost to be $1,623,000. Initial work includes low taintor-gate dam, 72″ intake pipe 1200′ long, 6′ x 6½′ tunnel 7850′ long, fine screening and chlorination plant, 4000′ extension of dist. system, and a 5 mi. supply line to industrial district on city's Puget Sound water front. Present system supplies 9,170 customers and estimated population of 36,000. New supply necessary for expanding pulp and paper industry which requires from 60,000 to 100,000 gal. of water for each ton of pulp produced. Water must be of high quality, free of color and turbidity which may be detrimental to quality of finished paper stock. One of present supplies, Lake Whatcom will be utilized. Water will be drawn from a different location in the lake and separated from present source by dam. Cap. new supply 6,420 mil. gal., low water flow into this lake about 18 m.g.d. Present new development sufficient for demand up to 30 m.g.d. further water to be obtained from diversion of 60 m.g.d. from South Fork of Nooksak R.—*Martin E. Flentje.*

Construction Progress on Eureka's Water Project. CLYDE C. KENNEDY. W. Cons. News, 12: 387 (Oct. '37). 24 hr. schedule being carried out on Mad R. water supply project for Eureka, Calif. Review given of conditions found in dam foundation requiring revision of original plans. Modified plan calls for construction of dam to elev. 200, approx. 50′ above low water, with provision for raising in future to elev. 260; and 5 m.g.d. cap. gravity pipe line from dam to city low level res. Pipe line to be 5400′ — 24″ and 15,000′ — 30″ steel-cylinder pipe with spun mortar lining and reinforced Gunite coating, 3 siphon river crossings, 5 siphon slough crossings, a tunnel 900′ long and 51,400′ of 36″ redwood stave pipe all installed above ground, with numerous short-span structures over small drainage gulches and channels. Total cost of project approx. $2,000,000.—*Martin E. Flentje.*

METERS

Meter Testing Methods and Program of the East Bay Utility District. THOMAS I. CASEY AND J. S. STEVENS. W. Cons. News 12: 385 (Oct. '37). Well over 1 mil. dollars invested in 135,000 meters in daily use by patrons of East Bay Mun. Util. District with net consumption over 55 m.g.d. during peak period. Proper design, coupled with accurate and careful workmanship, is governing factor of a successful meter which must be accurate when new and after long use; must withstand temp. changes, corrosive action, electrolysis; and constructed to prevent deposition of material in interior parts. Use of meters over 30 yrs. old indicates requirements are met. New meters rec'd. by district recorded and subjected to accuracy tests. A.W.W.A. specifications used and meters rejected if these not met. Improvements in testing allow 120-⅝″ meters to be hooked up in series and tested. With 2 test ma-

chines 6 men test 120 meters per day on ¼ and 2 g.p.m. flows at cost of 37¢ per meter. 10 cu. ft. test used due to convenience of reading dials of meters, interpolation allowing direct reading of percentage of registration to nearest tenth of 1%, by careful measurement, 10 cu. ft. will thus register the percentage of accuracy of each meter. Meter shop also equipped with 100 cu. ft. tank for testing from 3″ up to and including largest compound and detector meters. Card system maintained including record of each meter in system. Description given of new slide rule for determining correct gear ratio for any set of meter gears to produce any desired percentage of increase or decrease in relative speed. Manometer also developed for obtaining frictional pressure loss, and many research problems investigated. In one a break-down test involving 5 meters of each make used is being made involving one set of meters on intermittent flow simulating household use and a second set on continuous flow. Has been going on 4½ yrs. equivalent to 270 yrs. av. consumer use. Results of this test not given.—*Martin E. Flentje.*

Size of Meters for Services. SAMUEL H. MACKENZIE. J.N.E.W.W.A. 51: 367 (Dec. '37). Meter size should be determined by consumption and rate of draft. Ordinary household flows in g.p.m. are; kitchen sink, 5; toilet with tank, 5; bath tub, 5; lavatory, 3; garden hose with nozzle, 7; 50′ hose, no nozzle, 11. Tests on a ⅝″ meter at 22 g.p.m. flow gave pressure loss of 15 lb. per sq. in., ¾″ meter at 34 g.p.m. 17 lbs., and 1″ meter with 48 g.p.m. 20 lbs. Fair requirements for domestic service are for 1, 2 and 3 family house respectively about, —15, 22 and 30 g.p.m. ⅝″ meter ample for 2 family house unless flush-valve toilet used which takes nearly 20 g.p.m. Recommends test of service with recording meter before regular meter placed.—*Martin E. Flentje.*

DISTRIBUTION

Submarine Pipe Line Laid Under Los Angeles Harbor. ANON. W. Cons. News, 12: 393 (Oct. '37). To supply est'd demands of 20—25 m.g.d. from fish canneries on Terminal Island opposite San Pedro new 20″ c.i. line, 1400′ long, was recently laid by Los Angeles Water Dep't. New pipe added to present 12″ and 16″ submerged c.i. lines. In laying, 4 of the 15′8″ lengths were bolted together and laid as a section. When assembled each section was picked up by a "strongback," handled by derrick on barge and lowered into underwater trench and joints bolted up by diver. Contract involved $53,007. —*Martin E. Flentje.*

New Data on Pipe Joint Strength. LEON SMALL. Eng. News-Rec. 120: 180 (Feb. 3, '38). Tests of pull-apart strength of 30″ Metropolitan type c.i. pipe joint recently conducted by Baltimore Bur. of Water Supply. Behavior under both hydraulic pressure and external loading determined. Test procedure and results described, latter indicating that load of 25 tons can be safely applied. In hydraulic test, joint was deflected about 10° and then brought back to straight line. When pipe was filled with water, joint wept considerably, necessitating slight caulking by hand before applying test pressure. No appreciable movement noted until pressure of 50 lb. was reached, corresponding to total load on joint of approx. 25 tons. From then on a constant move-

ment was observed and when pressure reached 200 lb. joint had moved so much that lead was forced out, releasing pressure. External loading test made to determine effect of repeated loading. Total load of 15 tons suspended by the joint was raised and lowered 100 times. Slight movement after fiftieth lift, after which no further movement observed. Flexible joint made in usual manner by first greasing spigot end with graphite grease, pouring the joint with virgin lead and caulking.—*R. E. Thompson.*

Fabricating Concrete-Lined Steel Pipes for Water Mains. ANON. Can. Engr. 74: 5: 3 (Feb. 1, '38). Fabrication of welded pipe for 7.5-mi. main which will deliver water from Toronto's Victoria Park purification plant, now approaching completion, to high level districts of city is described and illustrated. Pipe 48″ i.d. and lined with cement in shop and covered with concrete in trench. Steel plates are $\frac{1}{2}$″ and $\frac{9}{16}$″ and each 30′ length made up of 5 sections welded together. Prior to lining, each length and special is subjected to hydraulic test, pressure used being 195 lb. per sq. in. for $\frac{1}{2}$″ plate and 255 lb. for $\frac{9}{16}$″. Reinforced concrete lining, 1½″ thick, is placed centrifugally, reinforcing being tack welded to inside of tube. Elbows and specials lined with gunite, trowel finished. Concrete lining deposited while tube is rotated at approx. 700′ per min. on inside of periphery, speed then being gradually increased and maintained at approx. 2500′ per min. until about 70% of mixing water has been driven off and concrete has set sufficiently to remain in place. Lengths are moist cured for 10 days before shipping to field. Concrete has min. strength of 4500 lb. per sq. in at 28 days when tested by standard procedure and 7000 lb. in place. All joints welded, shop work being largely automatic.—*R. E. Thompson.*

New 48-Inch Steel Cylinder Concrete Pipe and Carrying Structure. C. T. HEENEY. Can. Engr. 74: 4: 5 (Jan. 25, '38). The 35-m.g.d. purification plant of Ottawa, Ont., is located on Lemieux Island in the Ottawa R., from which the supply is drawn. Until recently water from the pure water reservoir was conveyed to city by dual pipe lines suspended on reinforced concrete arch bridge connecting island with mainland. This was considered potential hazard to the supply, as failure of bridge might result in fracture of both pipes. To correct this situation, new line was recently installed at cost of $160,000 on independent steel carrying structure erected for the purpose, provision being made for second line at some future date. Pipe, which is 48″, consists of $\frac{3}{16}$″ electrically-welded steel cylinder lined and covered with 1¼″ and 2″, respectively, of reinforced concrete. Lining placed centrifugally and reinforced longitudinally with twenty $\frac{1}{4}$″ uniformly spaced rods and circumferentially with spiral of $\frac{1}{4}$″ rods having uniform pitch of 4″. Covering placed with vibrators and reinforced longitudinally with twenty $\frac{3}{8}$″ uniformly spaced rods and circumferentially with spiral of $\frac{1}{2}$″ rods having uniform pitch of 2⅝″. Clearance between reinforcing spiral and steel cylinder was $\frac{1}{2}$″. Specifications required concrete strength under compression of not less than 3,000 lb. per sq. in. after 28 days. Steel cylinder, with reinforcing, was proportioned to withstand working pressure of 125 lb. per sq. in at tensile stress not exceeding 12,000 lb. per sq. in. in steel. Pipe lengths were 16′. Total length 2,213,′ 619′ being supported on the carrying structure. Joints were of bell and

spigot type, using hemp and lead for jointing material, surrounded with reinforced concrete collars. Seven Dresser couplings used as expansion joints. The section on the pipe-carrying structure is exposed to extreme weather conditions, necessitating insulation. Before placing insulation, 1¼″ steam pipes were placed on either side of the pipe and covered with a half-section of 4-ply pre-shrunk asbestocel insulation 1″ thick. Whole was then covered with layer of high-rib expanded metal of sufficient strength and rigidity to hold insulation (applied later) away from pipe. In this way, an air space, within which are the steam pipes, was created next to the pipe. Two layers of best quality rock cork were then applied, held in position with ½″ Signode stripping placed 12″ apart. Over the cork was placed ½″ wire mesh to which was applied asbestos cement felting with min. thickness of ¼″ and then a coat of plastic asbestos asphalt weather-proofing compound with min. thickness of ¼″ and so compounded as to withstand weather and resist drying and cracking. Latter coat was trowel-finished to smooth surface and painted, together with supporting structure, with aluminum paint. Insulation contractor was required to guarantee, independent of steam lines, which were placed by civic forces as additional protection: (1) the elasticity of the weatherproof coating, (2) that insulation was sufficient to prevent still water in pipe from freezing during 6-hr. period with atmosphere temp. of −30°F., and (3) that no ice will form on interior walls of pipe when min. flow of 4 m.g.d. is maintained. Thermometers have been inserted in the air space around pipe line and steam pipes, which are connected to a low-pressure boiler, will be used if necessary. Details are included of procedure followed in locating the piers of the supporting structure, in constructing the latter and in making the connection to the concrete filtered water reservoir, 12′ 6″ below top water level, while reservoir was in service.—*R. E. Thompson.*

Securing Uniform Quality from Varying Raw Water. JEPTHA A. WADE. W. Cons. News 12: 383 (Oct. '37). Zones in territory in Menlo Park-Atherton-Woodside area of Calif. Water Service Co. in which changes in taste, color and hardness were frequent led to improvements in '37 costing nearly $70,000. Included 3½ mi. 15″ transmission main for bringing San Francisco water to system, 250,000 gal. steel tank, aerator, booster pump, chlorination tank, controls, flow meters, etc. San Francisco water to be used with chlorinated aerated company owned Bear Lake Gulch water in varying proportions to produce output of uniform character. Will result in water of lower av. hardness, higher pH and within 10 lb. pressure range instead of former 20. Transmission pipe made of spiral welded steel, No. 10 gage, 16″ o.d., fabricated in 30′ lengths. Protected against soil corrosion by 2 layers asbestos felt laid in hot asphalt. Pipe cement lined by centrifugal process with ⅜″ to ½″ cement grout. Lengths joined with Dresser couplings. Specifications for leakage at 150 lb. pressure for 2 hrs. to be less than 700 gal. per mi. (4 gal. per joint) quite easily met, actual leakage of some sections being from 10% to 50% of this specified amount.—*Martin E. Flentje.*

Solution of Transmission Problems of a Water System. (*Discussion of previous paper by E. H. Aldrich*). HAROLD E. BABBITT AND C. MAXWELL STANLEY. Proc. A.S.C.E. **64**: 380 (Feb. '38). Professor Cross' method for

the analysis of flow in networks and conductors makes it possible to solve any problem which may arise and to any desired degree of precision. Cross' method of balancing flows is more difficult than his method of balancing heads and some problems involving the former method may be more easily solved by a trial and error method using the latter method. The art of designing distribution systems has developed slowly and has been out-distanced by the developments in supply, treatment, and conditioning of water. In several municipal water systems in Iowa the cost of the distribution system represents nearly two-thirds of the total investment in the water works. The graphical solution outlined by the author seems to be much better suited to problems of transmission or distribution which involve not more than a few parallel circuits, than to complicated grids with numerous circuits or cross-connections.—*H. E. Babbitt.*

Fire Hydrants, Design, Operation, and Maintenance. W. A. RADSPINNER et al. Bul. Am. Ry. Eng. Assn. 39: 198 (Dec. '37). Fire hydrants in common use on railroads are of the type with valves closing against the water pressure, those closing with the water pressure, and the slide valve type, which are described and illustrated. Importance of adequate drainage is emphasized. It is necessary for railroads to use threaded connections of the same size and type as the local municipality, but the National Standard is recommended wherever possible. It is important that authentic record of hose coupling sizes be maintained in order to facilitate repairs and replacements.—*R. C. Bardwell.*

An Improved Tapping Machine. ANON. Eng. News-Rec. 120: 261 (Feb. 17, '38). Improvements made in water main tapping machines used in Los Angeles are described briefly, including means of preventing sagging of boring bar while making horizonal taps, avoiding rocking of the machine parallel to the main and elimination of side thrust on the boring bar. Mains of 10″ diam. and upward have metal thickness considered safe for connecting 1½″ cocks; min. main diam. for 2″ tapped connections is 12″. Found preferable to tap large mains slightly above the mid line: this avoids drawing off debris that tends to float or sink and reduces the necessary trench depth.—*R. E. Thompson.*

Home-Made Shop Aids. ANON. Eng. News-Rec. 120: 304 (Feb. 24, '38). Brief description of 3 pieces of equipment which speed up and simplify operations in machine shop at Pasadena Water Dept. pipe yard, namely: (1) 2-compartment bin on wheels for picks that are brought in for sharpening; (2) sheet-metal rack, also on wheels, which serves both for storing sheet metal and as a cutting and assembly bench; and (3) a very heavy metal table used for many operations that otherwise would have to be performed on floor or on limited space available on anvil. Latter consists of circular crank and shaft from an old Corliss engine. It was set up with the 6′ shaft projecting down into pit filled with concrete. Surface of circular top, 40″ in diam. is 29″ above floor level. At the flange, wheel is about 5″ thick: most of remainder is 2″. For convenience in bending pipe and similar operations, a wide groove was machined around periphery of wheel prior to mounting.—*R. E. Thompson.*

Protecting Reservoirs from Bird Nuisance. ANON. Eng. News-Rec. 120: 110 (Jan. 20, '38). For many yrs., reservoirs in San Francisco have been effectively protected from sea gulls by simple expedient of stringing wires above water surface. When a new reservoir was built some yrs. ago, spacing of wires was increased from 30′ to 50′ each way to reduce cost. With this arrangement, gulls occasionally alighted on reservoir. Placing of intermediate wires, particularly a few diagonal runs, proved a prompt corrective. Conclusion reached is that spacing should not be greater than 30′ each way and possibly 25′ would be a safer distance. Size of wire is not important, min. diam. necessary to span reservoir being quite sufficient.—*R. E. Thompson.*

WELLS AND GROUND WATER

Prevention of Methane Gas Explosions at Water Wells. H. A. SPAFFORD. The Illinois Well Driller **8**: 3 (Mar. '38). Several serious gas explosions have occurred in Illinois in past few years of water wells. Two general causes are: 1st, evolution of gas from water in the well. If the casing top is not sealed and is improperly vented an explosive mixture may result in the well pit or the pumping station, or 2nd, the escape of methane from solution in the water after it has been pumped from the well due to change in pressure and temperature. It has been found in many cases that the so-called "air cushion" in small pressure tanks is mainly methane. Concluded that the elimination of possible methane gas explosions can be accomplished by sealing top of casing with gas-tight seal and equipping the sealed casing with a gas-tight vent pipe having discharge to the open air outside of buildings at a point inaccessible to open flame. The end of the vent pipe should be turned down and screened with no less than 24 meshes per in. Found that aeration of methane-containing water in a common coke-tray aerator reduces amount of methane to a point where there is little or no possibility of the remaining gas in the water resulting in an explosion. The aerator must be screened to avoid contamination and it must be placed out of doors. The gravity storage tank receiving the aerated water should be vented with a 2½-in. or larger, pipe extending to an inaccessible point in the open atmosphere.—*H. E. Babbitt.*

New Formulas for the Calculation of the Yield of Wells. SETINSKI VICTOR. Gas- u. Wasser **80**: 810 (Nov. 6, '37). A non-dimensional factor for the calculation of the flow in permeable material is developed in the following way: The flow through a vertical pipe of length h in which water flows under this head h will be $Q = A\sqrt{2gh}$. If this pipe is now filled with permeable material to the height h the area of flow is reduced from A to mA and the velocity from v to nv and the flow reduces then from Q to $Q_o = mnQ$. The permeability is thereby measured by the ratio $Q_o \div Q = mn = P$. This factor P can be determined experimentally. Underground flow is then calculated by determining the area A and the velocity $v = \sqrt{2gh}$ and by using the simple law $Q = PAv$. The determination of the area offers in general no difficulty but the selection of the actual pressure head h has to be done with careful consideration. Several cases of inflow into drainage channels and into wells are fully calculated and the method used to determine the effective head is shown. All cases discussed deal with the condition in ordinary wells. The depth of the water-bearing strata is h_o, the depth of inflow into the well h, the draw down

$h_o - h$, and r the radius of the well. The formulas have been developed primarily for the case of drainage ditches but are applied also to wells. It is shown that in wells reaching to the bottom of the water-bearing strata the velocity of out-flow in the case the well is pumped to the bottom is $0.575\ n\ \sqrt{2gh_o}$, that is the velocity head is $0.33h_o$. If the well is only partially pumped then the inflow is $Q = 2\ Prh\ 0.575\ \sqrt{2g(h_o\text{-}h)}$. This formula shows that maximum inflow occurs for $h = \frac{2}{3}h_o$. It obviates therefore the inconsistency of the ordinary formula (as stated for example by Turneaure and Russell) which gives maximum inflow for $h = o$, that is when there is no area of inflow. The radius of influence does not appear in these new formulas. It can be calculated from the time of the recovery of the well after shutting down the pump and by the assumption of a certain shape of the draw down curve. The author assumes it to be elliptical. The radius of influence is only used for the determination of the spacing of wells. Neither does the slope of the draw down curve appear, as the surface curve is produced by the velocity and not the velocity by the curve. The velocity is not a function of the slope but of the pressure height. The velocity increases towards the outlet because the pressure height increases. The new formulas are therefore theoretically justified as they are built logically from these considerations.—*Max Suter.*

Ground Water Pollution and the Bored Hole Latrine. E. L. Caldwell and L. W. Parr. J. Infect. Dis. **61**: 148 ('37). This is a long but very useful account of an investigation into the contamination of ground water from bored hole latrines. The investigation has been carried out by the Alabama State Dept. of Health and is one of the most complete yet recorded. Bored hole latrines very common in the Far East and spreading to other parts of the world, especially to Central America and the West Indies. The latrine usually consists of a cylindrical boring 10″ to 25″ in diam. reaching to such a depth as to penetrate into the ground water. The idea is that in this manner septic decomposition of faecal matter will be effected, but on the other hand the accepted hygienic viewpoint is that the safe disposal of excreta should preclude water contamination. Studies in Covington Co., Ala., extended from '29 to '33 and covered investigations at 8 bored hole latrine installations. Each latrine was surrounded by a series of wells and frequent examinations of the water pumped from the wells was made, the effect of the rate of pumping being observed. Data obtained showed clearly that faecal organisms do not travel to significant distances in all directions from a concentrated source, as is usually believed, but are carried only with the ground water flow. Intensive observations were then made on one particular bored hole latrine and the influence of faecal matter in test wells located from 5′ to 35′ from the latrine was noted and the rate of recovery of infected wells was investigated. The course of bacterial contamination was followed by frequent examinations of water samples for organisms of the colon-aerogenes group with emphasis on the recovery of typical *Bact. coli* and with noting of *Cl. welchii*. In addition complete chemical analyses of the waters were carried out from time to time and, as one might have expected, pollution does occur mainly in the direction of flow of the ground water. Whilst the results obtained are only applicable to the specific conditions regarding soil, ground water, climate, etc., certain

general conclusions emerge but they would have to be modified according to the local circumstances of each individual case.—*B. H.*

Experiences With Low-Velocity Gravel-Packed Wells. PAUL F. HOWARD. J.N.E.W.W.A. 51: 424 (Dec. '37). Experiences with wells in several Mass. cities is recounted. *Attleboro.* Pumping results on 14 test wells and 3 observation wells driven in '24 indicated area immediately tributary to wells was insufficient to produce rate of 0.40 m.g.d., however water supply system was installed in area in '29 and '30. Included 88-2½″ diam., 20′ to 32′ deep, driven wells connected to pumping cap. of 1.5 and 2.5 m.g.d. (total of 4.0 m.g.d. if two pumps operated together). Iron content of water at first test 0.15 p.p.m., after system placed in use rose rapidly to 0.98–1.94 p.p.m. Investigation by authors firm in '34 showed av. entrance velocity of water to wells of 81 ft. per min. on assumption soil had av. porosity of about 35%. Entering area of water only 4.9 sq. ft. Condition remedied by removing fine top soil 20″ in depth; installation of specially designed, low-velocity, gravel-packed wells with diams. of 52″ at bottom and 64″ at top, averaging 22′ in depth; and arranging to flood area from pond. These wells were to be pumped at low uniform rate. Test results satisfactory, draw-down at 0.432 m.g.d. rate for 24 hrs. was but 4′, after stopping, 2′ of draw-down recovered at once, remainder in 2 days. Water of good bacterial quality; av. iron content—0.20, and during flooding of area 0.15 p.p.m. During following months av. Fe was 0.15, free NH_3 0.005 and color 15 p.p.m. *Cotuit.* 4 similar wells, 52″ in diam., 30′ deep, 200′ apart installed in '36. During test lasting 8 days at av. rate of 0.345 m.g.d. draw-down was 5′ and 5.7′, recovering in short time after stopping pumps. Wells in large sandy area, surface material to depth of 9′ with eff. size of 0.48 mm. and unif. coef. of 3.1, under this down to 30′ depth sand with eff. size of 0.16 mm. and unif. coef. of 2.6. Av. Fe content—0.18 p.p.m., 2–500 g.p.m. pumps installed. *Harwich.* 4 gravel-packed wells installed in '36. When pumped at 0.275 m.g.d. for 6 days, 2 had draw-down of but 21″. Wells located in large valley having top sand with eff. size of 0.18 mm. unif. coef. 4.1; underlying stratum 5′ to 18′ thick with eff. size of 0.44 mm. and unif. coef. of 3.6. Fe content of water 0.09 p.p.m. Total high lift pumping cap. 1000 g.p.m.—*Martin E. Flentje.*

The Needham Gravel-Packed Well. BAYARD F. SNOW. J.N.E.W.W.A. 51: 409 (Dec. '37). Since Feb. '37 large part of water supplied Needham, Mass. comes from a gravel-packed well in SW corner of town approx. 600′ from Charles R. Underground water as source of water supply is often neglected; among advantages are volume of water that is generally available; infrequency of pollution; evaporation and leakage losses can be ignored; fact that required land is negligible. Local conditions in Needham particularly favorable to development of wells, town peculiar in that it has more frontage on Charles R. than any other town and yet was forced to consider water supply from other source than river. Charles R. valley has served for many yrs. as water supply for its towns and industries, most supplies being from wells or filter galleries. River's watershed above Needham, 180 sq. mi., includes all or large part of 13 towns, smaller parts of 7 more. Seven towns get water

supply from area, aggregating 2.5 m.g.d. As river loops around Needham 40 additional sq. mi. added to watershed and 11.5 m.g.d. additional water taken. Ground water supply compared to surface supply: in both, yield dependent upon watershed. Relation between volume of res. and watershed area is factor in detng. safe yield. Factors in proper design of ground water supply same as for surface supply, being,—(1) sufficient tributary watershed; (2) sufficient storage to compensate for differences between replenishment and draft; and (3) hydraulic cap. of collecting works must be such to keep loss of head at min. At Needham available tributary watershed of Charles R. ample for many yrs. to come at any available point in town. The line between the functions of storage and hydraulic cap. appears to be clearly drawn in surface res. supply, but almost non-existent in underground supply. Head loss between entrance and outlet of surface water res. negligible, in underground supply loss in head in flowing through interstices in sand and gravel to collecting point always of considerable magnitude and frequently the determining value in fixing safe draft. Porosity and permeability important factors. Type of well depends on depth and nature of water-bearing strata and desired draft. At Needham test borings showed presence of 80′ to 100′ of aquifer above rock floor, mostly coarse material. Permeability between 200 and 300, an extremely high figure. Gravel-packed well specified, contractors' bids required to state draw-down of proposed well at 1-m.g.d., with bonus and penalty provided for. Contract awarded Layne-Bowler Co. of New Eng. on bid of $8000. Max. bonus of $600 was earned. Draw-down on official test was 2.6′ at 700 g.p.m. Diesel power provided, pumping cost for fuel oil (at 5¢ per gal.) on test was $3.95 per mil. gal. with rate of 702 g.p.m. against 272.5′ and $5.85 per mil. gal. at 349.5 g.p.m. against 309.3′. The draw-down in a well is made up of depletion of storage and creation of slope to cause flow. Total draw-down at Needham when pumping at 1-m.g.d. (design point) was 2.6′, measured from original static level in well. When pumped at 4.5 m.g.d. during afternoon and evening of test, limit of draw-down not reached, 8′ max. recorded, 11′–12′ indicated. Two wells 1450′ away responded to any pumping rate continued long enough to establish slope, difference in water elev. under draft was found to be nearly 2′ per m.g.d. Author believes too much emphasis cannot be placed on thorough search for favorable area before deciding upon a water supply. Most important factor in underground supply is permeability of material conducting ground water to well.—*Martin E. Flentje.*

Additional Ground Water Supply for Woburn, Mass. JOHN P. WENTWORTH. J.N.E.W.W.A. 51: 430 (Dec. '37). Since first works in 1873, water supply for Woburn has been directly and indirectly from Horn Pond. This pond, in southern part of town, has surface area slightly over 100 acres with watershed of 7.5 sq. mi. Supply first taken from 82′ long filter gallery, with emergency connection to pond. This added to in '08 by installation of 20′ diam. suction well; 50-2½″ driven wells in '09, av. depth 45′; a gravel-packed well in '27, 40′ deep with yield of 0.75 m.g.d.; 3 gravel-packed wells in '31, of 65′, 70′ and 57′ depth with yield of 2.9 m.g.d. One of these last wells now out of operation due to sand. Two additional gravel-packed wells installed in '35, one near Horn Pond and known as Horn Pond well and one as Lexington St. well.

These wells have 40′ driven steel casing, upper portion 54″ diam., lower portion 48″. Another 24″ casing placed inside outer casing, upper 25′ of Armco iron and lower 15′ of screens. Horn Pond well can be pumped, using 7-stage turbine pump operated by 150 hp. variable speed motor, at rates of 1.8, 2.2, 2.5, 2.9 m.g.d. Lexington St. well also has 4 speed motor. Horn Pond well water has hardness of 95, CO_2 of 15, pH of 6.9, and Fe of 0.02 p.p.m. Av. bact. count 5 per c.c. with coliform organisms absent. Lexington St. well has hardness of 60, CO_2–23, pH–6.1, and Fe–0.01 p.p.m. Cost of construction excluding land, eng., legal and administrative services totaled $109,051.—*Martin E. Flentje.*

HYDROLOGY

The Determination of the General Rainfall Over any Area. Wtr. and Wtr. Eng. (Br.). 39: 639 (Winter '37). Report of Joint Comm. consisting of representatives from British Rainfall Organization, Royal Meterological Society and Institution of Water Engineers. A precise detn. of the general rainfall over any area requires: (a) adequate distribution of rain gages of the standard patterns exposed in an orthodox manner, (b) critical examination of the records, (c) preparation of an isohydral map and the detn. therefrom of the general rainfall by the cartographical method. Sufficient number of fixed points in area must be known at which rainfall has been detnd. Above essential before considering length of rainfall record required to define av. annual rainfall and method computation of av. annual figure from any single gage records. *1. Standard types of instruments.* Diagrams are shown of standard rainfall gages known as Meterological Office, Snowdon, Bradford, Seathwaite and Octapent types. Inside diam. of collecting funnel of all types is 5″, expts. have shown no advantage in using larger gages. Usually made of copper which is recommended over galv. iron. Camden and taper type of measures for taking daily observations are shown, each having conical base enabling small quantities to be read with precision. 0.005″ mark shown, rain days have rain of this amount or more. Last 3 gage types named used at more isolated stations where readings can be made once a mo. only. General description of each given and for wetter stations following gages are suitable: Av. rainfall from 30″ to 50″-Bradford gage of 15″ cap., 50″ to 100″—Octapent of 27″ cap., 100″ to 170″—Octapent or Seathwaite of 50″ cap. Recording rain gages to be considered supplemental to ordinary gage to give details of rainfall duration and intensity. *2. Orthodox exposure of gage.* Definition of orthodox exposure followed much exptl. work. Standard procedure is to set gage in ground so that rim is at standard height of 1′, recommended that gage be surrounded by level turf, or by gravel or clinkers, and never by stone, concrete or brickwork to avoid splashing. Errors due to over-shelter may be loss due to obstruction of some rain, or gain due to deposited rain blowing into gage. These errors negligible if distance of gage from every object is not less than twice the height of the object above the rim of the gage. Over-exposure must be guarded against but no precise definitions are available as in case of over-shelter. *3. Procedure to ensure accuracy.* Instrument should be certified, dimensions accurate and gage funnel level. Instrument should not

leak and due consideration to exposure given. *4. Distribution of gages.* Number depends on extent and configuration of area and precision desired in final value. At least one gage should be established where readings can be taken regularly at 9 a.m., with special readings during particularly wet periods and record made of depth of fresh undrifted snow each morning. Suggestions given for min. no. of gages in any moorland area: for 500, 1,000, 5,000, 10,000, 40,000 acres respectively; no. of daily gages—1, 2, 3, 4, 8; no. of monthly gages—2, 4, 7, 11, 22; total—3, 6, 10, 15, 30. *5. Length of record necessary.* General rainfall over England and Wales has been evaluated back to 1727, figures most reliable since 1850. Outstanding feature is frequency of dry year occurrence during period 1730–1766. In England and Wales dry yrs. predominated from 1854 to 1858 and from 1892 to 1908; wet yrs. from 1872 to 1883 and from 1922 to 1937. No periodicity of either wet or dry yrs. noticeable from record. Period 1901–1930 adopted as normal by international agreement, many British tables use period 1881–1915. Long period must be used to detn. av. annual rainfall. *6. Computing average annual rainfall.* Comparison of shorter period records with standard of 1881–1915 in nearby territory will allow setting up ratios of rainfall. Mean of 3 or 4 ratio stations sometimes considered as representative of variations in an area of 500 sq. mi.; in waterworks problems usually desirable to limit to smaller area. *7. Methods of assessing general rainfall over an area.* Av. annual values are first plotted to nearest 0.1″ on maps of scale 2 mi. to 1″. In drawing maps estimates have to be made of rainfall in adjacent regions by reference to values at these points and configuration of land. General principles to be followed are: (1) area near west coast is wetter than similar area near east coast, (2) Mt. ranges at rt. angles to prevailing winds receive most rain, (3) valleys facing sea to south-west have small rainfall for longer distance up them than similar valleys facing other directions, (4) max. rainfall tends to occur on leeward side of ridges, (5) valleys surrounded on all sides by mts. have high rainfalls. Isohyetal lines then drawn at intervals of 5″ or 2½″. In small areas general rainfall over area can be detnd. by inspection of map; if large, cartographical method should be used in which areas between isohyetal lines are employed. *8. Assessing the general rainfall for shorter periods.* Month by month maps showing distribution of rainfall over an area may be employed using cartographical method; or method used in which rainfall of each yr. or mo. at each station is expressed as a percentage of the av. annual rainfall, these then plotted and the mean av. over the area detnd. by inspection. *9. Rainfall over area where gages are sufficiently numerous, but have been read for only a short period.* In areas where gages have been well sited and correctly read for 7 yrs. none of individual resulting figures will differ by more than 3% from mean, while av. will probably give true long av. to within 1%. In cases where few or only one standard gage record available, short term records may be used by applying percentage values of standard figures and calculating probable av.—*Martin E. Flentje.* (See also following abstract.)

Determination of Rainfall. ANON. Surveyor (Br.) **92**: 809 (Dec. 24, '37). Discussion of the report (see above abstract). The first part of the report is of elementary nature for the benefit of indifferent or uninformed authorities.

Report makes no provision for procedure in overseas Dominions, nor for measurement of snowfall. Committee's analysis of data and elimination of inconsistent observations is commended. Sources of errors in observations and methods of averaging are discussed. Suggests use of Bilham's formulas (see abstract in this Journal 30: 377 (Feb. '38)) and those of Ionides in applying rainfall observations to areas devoid of observations.—*H. E. Babbitt.*

Construction Design Chart, XXIV—Culvert Sizes. J. R. GRIFFITH. W. Cons. News. 12: 501 (Dec. '37). Chart has been prepared to help engineer make more intelligent guess on necessary culvert size for given drainage area. Based on modified Talbot formula $A = \left(\frac{C M^{\frac{1}{4}}}{4}\right)$ for rainfall intensity of 1″ per hr., in which A-sq. ft. area of necessary waterway, M = drainage area in acres, C = coef. for contour and topography of drainage area. Chart given in article provides easy means of solving problem.—*Martin E. Flentje.*

HYDRAULIC ENGINEERING

Symposium on Automatic Control. *Introduction.* CHARLES ALLEN THOMAS. Ind. Eng. Chem. 29: 1209 (Nov. '37). *Automatic Control and the Chemical Industries.* LUIS DE FLOREZ. Complete automatic control may be considered as necessary coordination without human intervention of (a) knowledge of conditions, (b) integration of these conditions with respect to time or some equivalent and (c) some manipulation which accords with this integration. Automatic mechanisms were formerly viewed as leading primarily to reduced labor costs. Today, advantages are seen to include centralization of instruments and controls, increased size of working units and accuracy of operation, with improved products and reduction in cost. Future trends will include more study in various fields for key variable to which other variables can be subordinated to bring whole process into field of potential automatic control. Applications to temperature control in oil cracking and to control of aircraft in flight are discussed. *Automatic Mixing and Proportioning of Gases and Liquids.* H. J. VELTEN. In most commonly used methods of measuring flow (orifice plates and Venturi tubes), power available for metering impulse varies as square of flow. To cover appreciable range, control should consist of a power relay operating without weight or friction, and capable of responding to minute impulses. Jet pipe control relay, which meets these requirements, consists of a jet pipe swinging on a hollow vertical pivot through which operating medium (oil) is supplied to jet at high velocity. As oil stream leaves nozzle, it strikes at two closely adjacent orifices in distributor communicating with two sides of double acting piston. Slightest change in controlling impulse acts on diaphragm which moves jet pipe causing oil to strike right or left orifice or between the two, moving piston or holding it stationary, to satisfy control requirements. Transometer embodies jet pipe principle but balances oil flow with compressed air flow which is used to actuate regulator. To maintain fixed ratio between steam load, air supply and coal supply to a steam generator, steam load can be measured by balancing pressure in header against constant value. Differential pressure is function of load and is balanced by

differential impulse representing air flow, which may be variously measured. Metering impulse proportional to stoker speed is obtained from metering fan driven by variable shaft of stoker drive and equipped with small Venturi inlet whose suction is proportional to square of speed. This principle can be applied to fans, boosters or pumps. For proportioning two fluids, both flows are measured with variable orifices. Constant differential is maintained across the movable orifice, and position of orifice used to give flow impulse to main proportioning regulator. Devices are also described for proportioning gases, including mixed fuels. Since present trend is toward increased flow ranges, cooperative research is needed on flow measurements through variable orifice plates. Control equipment should be based on sound engineering, supplied by reliable manufacturer, properly serviced and selected to suit needs. *Control of Liquid Level In Vessels under Pressure.* J. B. McMahon. Whether or not process to be controlled has a self-governing characteristic, e.g., tank with inlet at top and outlet at bottom, is factor in selecting automatic control equipment. If vessels is under superimposed gas pressure, self-balancing characteristics are nullified because of small influence of liquid head on rate of flow, and automatic control is needed. Open-and-shut and limit types of control mechanisms make large changes in controlled flow and will interfere with smooth operation of succeeding apparatus. Throttling or proportioning types produce valve lift changes proportional to liquid height, and will tend to smooth out variations in inflow through not as much as commonly supposed. Constant-level throttling mechanisms will prevent vessel from acting as surge chamber. "Averaging" control mechanism is recent development used to force variations in uncontrolled flow to be reflected as variations in liquid level with as little and as gradual variation in controlled flow as possible while holding liquid level within confines of vessel, which must have enough surface area to absorb surges within permissible level variation. In many cases true level can be measured by properly located ball float and connection made to control by efficiently acting mechanism, or if ball float is inapplicable, differential gage may be used. Important factors in applying "averaging" control are illustrated by detailed engineering specification sheet for ball-float liquid level controller. If correctly designed and built, averaging controller will not only avoid setting up surges by its own action but also force inflow surges to be absorbed within the vessel. Time period for reaching equality should be as long as possible. *Elements in Automatic Control.* John J. Grebe. "Capacity lag" is limitation on response of control equipment due to size of system through which change must be spread before equilibrium results. If rate of change is measured, deviations from desired value can be sharply reduced, e.g., in hydraulic governing mechanisms for water turbines and steam engines. "Transfer lag" is delay in applying desired correction after signal to control system. "Head lag" refers to delay in transfer, e.g., of heat or steam, because of additional head required to drive additional requirement through system. Control principles in regulating processes are: (1) measurement of forces or flows causing changes, (2) the observed deviation, (3) amount of inertia or capacity to be adjusted and (4) time required to detect changes and make corrections effective. In metered control (I), flow of controlled quantity is proportioned to primary flow independently of end result, e.g., combustion

control. Deviation control (II) may be only on-and-off control or operation may be smoothed out by controlling rate of valve action. Rate control (III) may be used alone or with (I) and (II) to increase speed of correction, i.e., to correct for "capacity lag." (III) may be used in crude form in some processes, or in most refined type, sensitive element itself actuates control, correlating position of indicator and rate of change. Damping control (IV) compensates for "transfer lag" and acts to give increased flow for period proportional to "transfer lag" regardless of "capacity lag." Future developments will probably include further application of all four types of control to single system. High grade combination control should be mechanically reliable and should operate fast enough to reestablish equilibrium within less than twice total "transfer lag." *Continuous Control Systems with Variable Characteristics.* H. M. SCHMIDT. By immersing thermocouple in gas-fired furnace, e.g., temperature can be controlled through system using electrical controls to motor-operated valve governing gas flow, or same result may be obtained with photo-electric cells as primary deviation detectors. Pneumatic automatic control system is described consisting of (1) measuring system for such quantities as temperature, pressure, flow, liquid level, etc., (2) control setting mechanism for correlating measurement and control, (3) pneumatic relay or pilot valve allowing compressed air to pass to or from controlled valve in response to control unit governing air pressure to control valve, (4) diaphragm valve which regulates flow of controlled medium. Systems described recognize direction, magnitude and rate of change of departure from control point, and can be adapted to processes with widely differing characteristics.—*Selma Gottlieb.*

Control of Ice Jams in Large Rivers. W. E. EWENS. Can. Engr., 74: 5: 11 (Feb. 1, '38). Two types of ice jams are discussed: those which are dependent on some key point such as a constriction in the channel and those in which ice mass extends to bottom of stream and is often many miles in length. Most effective method of combating ice jams is by use of thermit, invented by H. T. Barnes, which consists of mixture of powdered aluminum and iron oxide in steel cylinders. When ignited (electrically), temp. of 2500-3500°C. is attained in a few sec. Surrounding ice and water are broken down into oxygen and hydrogen, former being fixed by molten iron of container and latter uniting with oxygen of atmosphere, resulting in a powerful explosion, the slowest known. Explosion is noiseless and will not harm abutments or adjacent structures. Both the heat and explosion are very effective in loosening and cracking the ice. Actual no. of heat units generated is small but the high temp. is very penetrating. Temp. stresses are set up, particularly in extremely cold weather, and cracking continues for many hrs. In first type of jam, key is destroyed and in second type channels must be formed through which water can flow. Several examples are described. Sand, gravel, cinders, coal dust, sawdust and sodium and calcium chlorides have also been used with varying degrees of success.—*R. E. Thompson.*

Floods and Flood Control. THEODORE T. KNAPPEN. Eng. News-Rec. 120: 239 (Feb. 10, '38). Floods and progress in flood control during '37 are reviewed. In the design of flood-control structures, empirical methods are

slowly yielding to rational analysis. Various types of earth and rock dams are being used in increasing no., permitting wider selection of economic reservoir developments. In the design of walls and levees, developments in soil mechanics are providing solutions for the problems of subsidence and seepage. Difficulties which once appeared insurmountable in the protection of such places as Cairo, by levee raising, are no longer obstacles.—*R. E. Thompson.*

The Flow of Water in Short Channels. CHARLES FREDERICK JASON LISLE. J. Inst. C.E. (Br.) No. 2; p. 287 (Dec. '37). The article deals with the hydraulics of flow in open channels, particularly under the conditions of non-uniform flow. A flow at a depth less than critical depth is termed "rapid" flow and at a depth greater than critical is termed "tranquil" flow. The following notation is used:

v = velocity in ft. per sec.

g = 32.2 (gravity).

d = depth of water in the channel, in ft.

$\frac{v^2}{2g}$ = velocity head, in ft.

h = height of channel-invert above datum, in ft.

S = slope of channel invert, in ft. per ft.

i = energy lost by friction, in ft. per ft.

E_s = specific energy, $\left(d + \frac{v^2}{2g}\right)$

E_T = total energy, $\left(d + \frac{v^2}{2g} + h\right)$

ΔE_s = increase in specific energy between two predetermined depths of water.

L = length of channel, in ft.

$\Delta L = \frac{\Delta E_s}{S - i}$ — denotes length of channel between two predetermined depths of water, which is positive when measured downstream and negative when measured upstream.

In tranquil flow S is less than i, the net specific energy of the stream decreases downstream to a minimum at the free-outlet end, at which the depth is the critical depth. In rapid flow S is greater than i at the critical depth, the net specific energy increases downstream and becomes a max. when the depth is so reduced as to make i equal to S. To determine the depth of flow at any point in a channel it is first necessary to determine the critical depth, where E_s is a min. and the value of i by any convenient formula, such as Barne's. The relation between i and S will indicate tranquil or rapid flow. If the flow is tranquil and the values of L are plotted against their respective values of d a surface curve results from which the depth at any point in the channel can be determined. If the flow is rapid, critical depth will exist at the origin of the channel and uniform flow at a depth less than critical will exist at some distance downstream. By plotting L against d, as for tranquil flow, the depth at any point in the channel can be determined; the curve becoming a straight line with slope S when the flow becomes uniform. Under certain conditions a hydraulic jump occurs at a change from steep to gradual channel slope. The

height of the jump can be calculated by plotting, as abscissas, the momentum per second, plus the total force of the stream, and, as ordinates, the depth of flow for a channel with a horizontal bed. This can be taken as reasonably correct for a channel of gradual slope in designing for a model, or where exact measurements are not of great importance. The height of the jump will be the difference between the two ordinates to the curve where the point of change in slope or an obstruction occurs in the channel. Where water flows over a dam a barrier can be built across the channel below the dam to back up the water to the required height to form the jump. Tables and figures have been compiled in the article to suit most common types of channels but where other types are to be studied a chart is given by which to determine the factor by which to multiply the flows to keep them in proportion to the linear dimensions of the respective channels. Results of tests on models are reported showing graphical comparisons between theoretical and actual measured depths.—*H. E. Babbitt.*

PLUMBING HAZARDS

Public Health Hazards in Plumbing. U. S. Treas. Dept., Public Health Service Publication, (Dec. '37). Publication presents summary of plumbing inspection survey of Federal bldgs. in New York City and Detroit. Cooperative study made with WPA in period May, '36-June '37. Working force divided into 3 divisions,—(1) field inspections, (2) laboratory, (3) administrative and drafting divisions. In N. Y. City, 810 federal bldgs. were inspected of which 376 (5.8% of floor area) were 1 story in height, 104 (9.8%) 2 stories, 193 (10.9%) 3 stories, 17 (59.1%) over 5 stories—percentage figure being per cent of total floor area in each case. In Detroit, bldgs. totaled 96, of which 39 were 1 story (8.2% of floor area), 7–2 stories (4.4%), 31–3 stories (45.1%) and 4 story bldgs. –15 (23.4%); remainder 5 story or over and unclassified. No. of structures included respectively in (1) N. Y. and (2) Detroit respectively,—small residences 261-32; multiple apts., barracks and dormitories 59 6; office bldgs. 32–12; hospitals 32–12; unclassified 430–44. Mention is made of several types of plumbing defects hitherto seldom mentioned in survey reports. In one defect a water line was connected to the discharge side of a sewage ejector in a bldg. sub-basement. Water line was directly connected to cooling jackets of 2 compressors furnishing air to ejectors, discharge pressure of ejector being 40 lbs. and water pressure 55 lbs. per sq. in. Reduction of water pressure below pressure of discharging sewage would allow sewage to be forced back through cooling jackets into bldg. water dist. system. Another hazard found was a connection of a 2″ water line into a 6″ soil pipe for purpose of flushing sewer whenever stoppage occurred. Pressure due to stoppage or vacuum in water line would cause flow of sewage into water line. Several examples and illustrations are given of soil pipe installations over ice cans and food handling racks. Any leakage of soil pipe would definitely contaminate food. In report, term "disapproved" is used to denote those fixtures which fall in the category of plumbing installations which, under certain conditions, may present a hazard to the public health. No. of fixtures inspected in N. Y. City and De-

troit were 21,928 and 2,736 respectively, a total of 24,664. No. listed as disapproved in N. Y. was 14,844 and in Detroit 2,052 being respectively 67.7% and 75.9% of the total plumbing installations inspected in the 2 cities. Numerous tables and graphs give the results of inspections, subdivided into types of fixture, type of bldg., etc. A partial list of the consolidated figures follows: lavatories—total inspected 7,680, total disapproved 6,547, a percentage of 85.2% hazardous; similar figures for flushometer closets are total 5,156, disapproved 5,156, 100%; low tank closets, total—853, dis.—851, 99.8%; high tank closets, total—611, dis.—611, 100%; bath tubs, total—1,229, dis.—842, 68.5%; laundry traps, total—791, dis.—480, 60.7%; sinks, total—1,592, dis.—62, 3.9%; drinking fountains, total—800, dis.—716, 89.5%; pumps, total—73, dis.—21, 28.8%; laundry washers total—32, dis.—32; 100%; boilers, total—338, dis.—331, 97.9%. Attention is called, in conclusion, that it is necessary to understand fully the conditions under which plumbing fixture or installation may become a public health hazard. Design must be such that a direct or indirect path for contamination is furnished and occurrence of conditions which would permit contamination must be possible. The paths through which contamination may be spread through a plumbing fixture or installation can be det'd, and may be direct or indirect and obstructed by valves, siphon preventers, and air gaps. In the survey reported no cognizance taken of fact that probability of conditions necessary to spread of contaminations varied in different bldgs.; the presence of a definite path by which contamination possibly could be spread was sole basis for approval or disapproval. Noted in survey that probability of conditions req'd for spread of contamination varied in different bldgs. Impossible in this survey to detn. a frequency factor for different type of fixtures and bldgs. Survey shows plumbing defects and cross-connections exist in federal bldgs., some of which are of immediate danger to health of water users of bldgs. in which located, others are of remote significance unless other variables brought into play. Because approx. same number of defects in Detroit bldgs. as in N. Y. City, it is believed same conditions exist in federal bldgs. in other cities and in other public bldgs. generally.—*Martin E. Flentje.*

Danger of Sickness through Improper Household Plumbing Installations. H. SCHELLENBERG. Monatsbulletin (Swiss) 17: 266 (Nov. '37). Original preparation of pure water is not alone sufficient protection against water-borne disease; care must also be taken against contamination in distribution system. This may be possible through connection between water supply and sewage or waste water system, through open valves in such connections, and through higher pressure in the sewage system. Such connections quite common, examples cited include syphon or ejector operating to empty pools, wash machines, baths, etc. Higher pressures may exist in waste lines when water system pressure goes below normal, as when reservoir goes dry, pipe line or pump breakdown occurs, and during water surges in lines. Examples are also given of back-siphonage through improper plumbing fixtures; vacuum breakers and automatic valves opening to atmospheric pressure described. Excerpts are given of French and German regulations concerning this problem.—*Martin E. Flentje.*

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